James Woodhouse

JAMES WOODHOUSE

A PIONEER IN CHEMISTRY

1770–1809

By
EDGAR F. SMITH
PROVOST OF THE UNIVERSITY OF PENNSYLVANIA

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To

M. A. S.

PREFACE

Offering to readers the biography of a man who ceased to live one hundred and nine years ago may call for explanation; if so, the reasons are at hand. First, the subject of this sketch was a chemist; second, the status of chemical science in our country, at present, is excellent, and in the future is bound to rise to an even more exalted position, so it is hoped that the student of its history, upon inquiring as to its rise and development, will welcome the facts pertaining to the labors and successes of its earliest pioneers. However, the records of these are widely scattered, and what is more, are rapidly disappearing. To assemble those still extant would require much time and enduring patience. The material presented in the life-story of James Woodhouse has been gathered through many years, and as it has grown and been studied there shone forth in it innumerable evidences of a splendid, masterly leadership, with data of exceptional value. For instance, if chemists were to pause and ask—were there chemists on these shores who took an interest and participated in the struggle waged about the new chemistry, as set forth by Lavoisier and his associates, when it was arrayed against

the strange doctrine promulgated by Becher, Stahl and hosts of devoted experimenters in many lands, the answer, so far as we are concerned, would be found in the labors of Woodhouse, who was foremost in establishing the teachings of the French School upon American soil? And, he was also a genuine leader in other lines of chemical endeavor, for he was a real investigator, who independently isolated potassium and published facts of unusual importance. Today, it is true, many of his observations would be held as trivial, but compared with contemporaneous contributors at home and abroad they rank exceedingly high. Further, Woodhouse introduced Robert Hare, Benjamin Silliman and others into chemical science; and it is conceded that they, too, became leaders in this field of research.

The writer has long cherished the hope that the rising generations of American chemists would seriously interest themselves in the labors of their earlier brothers, and as a slight contribution to that end he submits this story of the achievements of James Woodhouse, a pioneer in Chemistry.

E. F. S.

JAMES WOODHOUSE

A PIONEER IN CHEMISTRY

1770—1809

Philadelphia has always been a city of interest to people in every walk of life. History of every variety has been made in the City of Brotherly Love. Scientists turn to it to read the early records of their specialties; and to none does it appeal more strongly than to chemists, especially to those who cherish the past and the humble beginnings of their science.

It was in Philadelphia, then, that American chemistry laid its first foundations. It is generally conceded that this was in large measure due to the fact that Joseph Priestley, on his way to his exile home, tarried long in Philadelphia; and later, at intervals, found his way from Northumberland to gather with congenial spirits in the city. Indeed, Priestley sojourned here for weeks and months at a time that he might deliver a "series of lectures on the evidences of revelation to crowded audiences, including most of the members of the United States Congress, at that time sitting in Philadelphia, and of the executive officers of the Government."

"As many were obliged to stand as sit, and the doorways were crowded," wrote Priestley.

In this way and by other means he influenced the thought of the day, particularly that pertaining to the science of Chemistry. The young men of the city met and conversed with him. Elsewhere, it has been observed that Robert Hare, in the beginning of his experimental career, enjoyed the privilege of exhibiting his oxy-hydrogen blow-pipe to Priestley, and Silliman, the elder, notes with evident pleasure his meeting with Priestley in the home of the distinguished Dr. Wistar; while Thomas Twining (*Travels in America 100 Years Ago*) wrote, "We proceeded to Dr. Priestley's house in the upper part of High Street, in a row of small houses between Sixth and Seventh streets, remarkable for their pleasant appearance, standing back a few yards from the footpath, and having small gardens, separated by painted rails, before them. . . . It was here that the English philosopher, the benefactor of his country and of mankind by his discoveries in useful science, had taken up his abode. Having passed through the garden of one of the first houses, the door was soon opened by a female servant, who, saying that the Doctor was at home, conducted us into a small room by the side of the passage, looking toward the street. . . . In

a few minutes the Doctor, having quitted, probably, his studies, entered the room, and I was at once relieved from a sort of uneasiness which precedes an introduction to a great man, his countenance being exceedingly mild and good-natured, and his manner no less easy and conciliating. His person, short and slender, his age apparently about sixty, with an unaffected cheerfulness. . . . The Doctor received me with hearty kindness. He placed me near the fire, and took a chair by my side. I soon found that he was as inquisitive as he had been represented to be. . . . He passed from general to particular questions. . . . Finally, I took leave, much gratified with this personal introduction to a celebrated man, of whom I had heard a great deal, when a boy at school; his system of Chemistry—his phlogiston and anti-phlogiston and fixed air—then making much noise, and leading to various experiments upon balloons, etc., in which boys at that time, I among others, took a part."

This delightful visit of Mr. Twining was doubtless but a prototype of the hours spent by young scientists of Philadelphia in the company of the man who thus unconsciously inspired and to a great degree, molded their scientific proclivities.

The purpose of these pages is to present the

life-story of one who had been so influenced. It constitutes a very definite chapter in the development of Chemistry in this country, and the impression, after its perusal, will surely be that an acquaintance with James Woodhouse and his work is worth while. He was born in Philadelphia, November 17, 1770. His father, William Woodhouse, came in 1766 to Philadelphia from Alnwick, England. He had been an officer in the army of the young Pretender, and fought for the Stuart cause at Preston Pans. His mother was Anne Martin, daughter of Dr. William Martin of Edinburgh. Immediately after the marriage of the parents they came to America, making their home at No. 6 South Front Street, Philadelphia, where the father began business as a bookseller and stationer, and was esteemed "an industrious, worthy citizen." The mother was reputed to have been a most excellent woman, discharging all her social and family duties with fidelity and zeal.

James was the second son in the family. Records fail as to the others. Woodhouse himself never made any reference to his family. Rumor had it that he had become estranged from all his kindred. Be that as it may, careful inquiry in comparatively recent years has brought nothing to light. A collateral heir

disclaimed any knowledge of the family history, and assumed utter ignorance of the life experiences of the subject of this sketch; so that such facts as are at hand come from the writings of acquaintances, or from fragmentary records of former students. There seems, however, to have been an earnest desire on the part of the parents of Woodhouse to have their children enjoy the benefits of a liberal education, for James was enrolled as a pupil first in a private school, then in the grammar school of the University of Pennsylvania. In due course of time he entered the University (1784), receiving the honor of Bachelor of Arts with the Class of 1787. Three years later the Master's degree was conferred in course. He began, therefore, his academic life at the age of fourteen.

In those days the School of Medicine in the University was closely allied to the College; it had not completely severed itself from the collegiate work. Hence, it was natural that Woodhouse should have known the famous Doctor Benjamin Rush. In fact, he became his student, and was soon deeply attached to his preceptor, whose reputation and position in the medical world were beyond dispute. In the scientific and social circles of those early days Rush wielded a marvelous influence,

and reigned almost supreme. He had been of that brave group of fifty-six who affixed their signatures to the Declaration of Independence. He was a striking, outstanding character, and once said:

"Medicine is my wife; science is my mistress; my books are my companions; my study is my grave; here I lie buried, the world forgetting, by the world forgot."

Rush had been under the instruction of Joseph Black and was an able exponent of the doctrines taught by that renowned Scotch teacher, which partly explains how he came to be the first occupant of the Chair of Chemistry in the Medical School of the University of Pennsylvania (1769).

Woodhouse evinced a decided preference for chemistry very early in life, neglecting often other studies that he might engage in experimental work; this, and the knowledge that Rush was, indeed, an eminent scientist as well as a leader in strictly medical subjects, influenced Woodhouse, no doubt, in his decision to place himself under his supervision and preceptorship; and so he became a student of medicine.

In 1791, however, prior to the completion of his medical course, he determined to apply for the situation of surgeon in the army, then

assembling under the command of the late General St. Clair, and destined to chastise the Indians on our frontiers, who had committed repeated murders upon the citizens of the United States; and, upon the resignation of his fellow student, Dr. James Mease, who had been appointed surgeon, but who changed his mind, he received his commission. The horrors of that campaign have been often given to the public. Luckily, Woodhouse escaped the dangers of the dreadful defeat which the United States troops suffered on the 4th of November (1791), having been ordered to accompany the first regiment which was sent after sixty militia deserters, four days before the battle, and to meet a convoy of provisions which was daily expected.

During his military service communications passed from time to time to his friend and preceptor. Some of these have been discovered in the Rush collections, on file in the Ridgway Library. They are intensely interesting because, among others, they give evidence of Woodhouse's keen desire to learn everything possible of subjects pertaining to his profession.

The first of the letters was

Addressed to Dr. Benjamin Rush in Walnut
Street one door from the
corner of Third Street
Philadelphia

and reads as follows:

CARLISLE, May 27th 1791

DEAR SIR,

It was with some difficulty I procured a small quantity of the Poison vine, which will be delivered to you by a waggoner who sets off from this place in a few days. I have enclosed as particular an account of it, as I have been able to collect, if you think it is worthy a place in the *Museum* or *Magazine* you will oblige me by publishing it.

If I have anything worth communicating, I shall write you from Pittsburgh, I am Sir, your very
humble servant,
JAMES WOODHOUSE

D^r Benj. Rush.

The sketch of the poison vine referred to follows:

AN ACCOUNT OF THE EFFECTS OF THE RHUS RADICANS OR POISON VINE IN THE CONSUMPTION, BY JAMES WOODHOUSE

"When we reflect that the intermittent fever & the venereal diseases were once as incurable as the consumption is at present, we have every reason to expect, a remedy may be found, that will one day strike off the latter from

the list of those diseases, that are now said to be the reproach of medicine.

"Before my arrival at this place I heard of the good effects of the Poison vine in consumption, & have since had the good fortune of hearing the report confirmed by the patients themselves—the confidence they placed in the remedy induced me to inquire particularly into its effects and publish the following account from which if any person gives it a fair trial, & it is found to fail, I can only say, it will add to the numerous medicines that have been celebrated for a day, & have as soon fallen into disrepute.

"This vine is found in the woods running straight up the sides of trees, & grows in great plenty in swampy ground & the sides of creeks. It adheres very close & is with difficulty disengaged from the trees. It is estimated by a number of the inhabitants about Carlisle as an effectual remedy in the consumption. The method of using it is to scrape off the external bark, cut about a handful of the inner bark & heart of the vine in small pieces, boil them in a quart of water down to a pint of which a half pint is to be taken daily.

"It always keeps the bowells gently open, relieves the pain in the breast & in *two* cases increased the secretion of saliva to a great degree. The inner bark has a taste considerably saccharine, the heart of the vine has little sensible effect on the tongue, if any, it is that of being slightly astringent. It should be prepared fresh every other day as it ferments by keeping.

"A Mrs Smith near the blue mountain, a Wm Elliott near the river Juniatta, have been perfectly cured by it.

"Jonathan Foster, a shoemaker by trade, is asthmatic & at times afflicted with a pain in his breast, he is now using the poison vine & experiences great relief from it.

"Hiram Gardiner, a shoemaker by trade, at the age of seventeen was afflicted with a pain in his breast, night sweats & tickling cough, he was said, by his attending physicians to be in a consumption, & by his own account, they could do nothing for him, he took to the use of the Poison vine, & by persevering in the use of it for a considerable time was perfectly cured.

"He now works at his trade in Carlisle, & is ready to relate his case to any person who pleases to wait upon him.

"I am informed the poison vine grows in great plenty down in the neck near Philadelphia."

Carlisle May 27th 1791

CAMP NEAR FORT PITT July 19th 1791

DEAR DOCTOR,

Having an opportunity I send you a small quantity of the extract of Poison vine, with a specimen of the bark of a bitter aromatic vine, which grows in abundance on the banks of the Ohio.

Concerning the effects of the Poison vine I have but one fact worth communicating, a gentleman, who used it in the consumption had an eruption produced over the whole surface of the body & and was perfectly cured by it.

The aromatic vine is not generally known by the inhabitants of Pittsburgh, even their Physicians are unacquainted with its virtues; the aroma & bitterness resides altogether in the external bark, the internal leaves scarcely any visible effect on the tongue.

Major ——— who gave me the first information concerning this vine, informed me Dr. Thoa——— carried a large quantity of it to Europe; unfortunately, I have had near fifty weight of it spoiled in drying. I shall gather more of it in a few days & send it to you by the first opportunity.

Our Hospital at present is a large Kentucky boat anchored in the Allegheny River, this answers three good purposes—first—it deprives our patients of the use of whiskey which, in my return to the Contractor I have exchanged for vinegar and soap—secondly—it prevents any contagious disease from spreading in the camp & thirdly—the dread of going to the boat prevents many from making imaginary complaints.

The epidemic which prevails at present is the Dysentery—blisters to the wrists after the fifth day never fail in giving a check to the disease.

On the 4th of July Brown & myself were called to an unfortunate soldier, who had the metacarpal & part of the carpal bones carried away by the bursting of a musquet—Brown was too timid to attempt the operation—I amputated the hand at the wrist in the presence of Col. Gibson, the officers of the army & several gentlemen from town. I dress him twice a day & he is in a fair way for recovering. I have a patient now under my care, with the symptoms of a Tetanus, from a wound which he received five weeks ago across the tendons of the fore arm in attempting to force a Sentinel; he complains of rigid & strong contractions of the muscles of the neck; used the mecurial ointment to his jaw & have given him as much bark & vine as he can drink.

When I mentioned this case, in the presence of Gen. Butler, Col. Gibson & Major Flodgrow, one of them said you were indebted to MacKnight for the discovery—I attempted to convince them of the contrary, & inform'd them of the certificate you receiv'd from Col. Stone.

Brown is acting the impostor—he has practiced Physic in the East Indies—was offered the Professorship of Botany in the college of New York & can tell the genus & species of a Butterfly flying. By such little arts does

he attempt to support the little reputation he has gained, he has decieved the weak & the ignorant, but men of penetration have found him out. Breckenridge says "*he knows too much to know anything.*"

Sir,

When I left Philadelphia I understood that no appointment, higher than that of a Surgeon's Mate was to take place in the Medical Department, since that I have been informed by gentlemen of very respectable characters, that new arrangements have taken place & a Surgeon is to be appointed to each regiment. I have written to Gen. Knox for the appointment you will confer an obligation on me by waiting upon that gentleman, & favouring me with a letter of introduction, to General Butler, General Sinclair, & any gentlemen you are acquainted with in Pittsburgh. The Surgeon's Mates are as ignorant as their patients.

We have no news concerning the Indians.

Please to present my compliments to M^{rs} Rush & family & students in the shop & believe me to be

Your very
H^{ble} Serv^{t}

Doctor Benj^{n} Rush JAMES WOODHOUSE

CAMP NEAR FORT PITT August 10th 1791

DEAR DOCTOR,

I take this opportunity of sending you a few pounds of the aromatic bark I promised you in my last letter. I have enclosed a piece of the vine along with the bark as there is something curious in its structure, being spungy, and at the same time pealing into many layers.

I have been in quest of the cancer root said to have been used by Dr. Martin & am now trying the lobelia as a ?

Brown has attempted to rob you of your discovery of the method of ? Dropsius (?), he told me he was of your opinion a long time, & gave you the first hint—he expects you will acknowledge yourself indebted to him when you publish—he has told the same to D[r] Bedford, who means to speak to him before a witness & write to you concerning it.

My patient who had the lockjaw is perfectly cured, & my respects to M[rs] Rush & the gentlemen in the shop

I am yours, etc.

JAS. WOODHOUSE

D[r] Benj. Rush

The curative effect of the poison vine in the case of consumption must have impressed Rush profoundly. He had himself suffered from the "white plague" and written extensively upon it throughout his life, for he had really cured himself.

The reputation Rush had attained in the use of mercurial preparations was so great that this medicament was recognized on all sides as having originated with him. Probably he smiled complacently on learning of the speeches of Surgeon Brown, who was led to send the following cruel, parting blow at Woodhouse:

FORT WASHINGTON Nov[r] 18[th] 1791

Woodhouse has behaved so ill to me, that had it not been for the respect I have for you, he should have been

sent home under an arrest, he was fourty miles off at the time of the battle and of course received no injury.

(Letter from P. Browne—Surgeon 2^d Reg. U. S. to Dr. Benj. Rush)

How could Woodhouse have participated in the battle when he had been detailed four days earlier to attend to other pressing duties?

On the return of Woodhouse to the University, after an absence of four months from Philadelphia, his medical studies were promptly resumed, and in May, 1792, having passed rigid oral, public examinations with the presentation of a thesis, he was admitted to the degree of Doctor of Medicine. The title of his inaugural dissertation was *On the Chemical and Medical Properties of the Persimmon Tree, and the Analysis of Astringent Vegetables.* It was encompassed in thirty-four printed octavo pages. In appearance it recalls the doctoral theses of the German universities. His father's name appears on the title page as publisher.

Much importance was attached to these publications in the earlier years of the Medical School of the University of Pennsylvania. Its library contains hundreds of such efforts at independent research. Indeed, in 1805, Caldwell selected twelve of these inaugural theses and published them in an octavo volume.

They were largely experimental in character. It was contended that public recognition "must have a powerful influence on the minds of the students in their endeavors to perfect their dissertations, and thereby render them worthy of such an honorable distinction." This plan was pursued for several years. Many of the theses were exceedingly meritorious. To this class belonged the dissertation of Woodhouse, which was "dedicated as a grateful tribute of respect" to Benjamin Rush, who in turn was pleased to write Woodhouse:

My dear Friend:

I beg you would permit me, to make use of a small part of a page, of your inaugural publication, on the *Persimmon Tree*, and the Analysis of astringent vegetables, as the vehicle of my acknowledgements, of the great pleasure I derived, from witnessing the zeal and industry, with which you conducted the experiments and studies, that have led you to the valuable discoveries, contained in your dissertation. I hope your success in those experiments, will animate you to direct your inquiries into other branches of Chemistry and Medicine, and that your eminence and usefulness in life may be equal to the ability and integrity with which you have discharged your duty to your

Affectionate Preceptor,
Benjamin Rush

May 3rd, 1792.

In the introductory remarks Woodhouse tells

that he chose the Persimmon tree for a thesis because "he wished on the one hand to avoid a thread-bare, worn out subject" and on the other that he might have "an opportunity of saying something on a tree, of which, little more is known than the name." He acknowledges also that he is "as yet, a Tyro in Chemistry."

The history of the tree is given and then attention is directed to the expressed juice of the unripe fruit, a substance of a singular nature. Seventeen different experiments were made upon it and commented upon by Woodhouse in these words:

"From the first of these experiments, it appears, that the juice of the Persimmon, contains the same acid, as all astringent vegetables; and from the second, we find it may be employed, as a nice test, for detecting the presence of iron, in mineral waters. In the third, it decomposed the iron, separating its principle of inflammability. In the fifth, we find a large quantity, of a transparent, brown, astringent gummy substance produced, which from some of the succeeding experiments, appears to be a gum-resin, with a proportion of excrementitious matter. The resin is a mild substance, generally containing a small proportion of the acid, and may be separated

from the gum, by precipitating the basis of the astringent, by the vegetable or volatile alkali, filtering the solution, and adding the marine or vitriolic acids. The gum is composed of the gallic acid, and the astringent basis, which is earth of alum.

"The property of forming a saline gum, with the earth of alum, is not peculiar to the gallic acid. The distilled acid of sugar, according to Schrickel, and the acid of tartar, have the same effect on that earth.* A gum resin appears to exist in almost every vegetable, which has the property of striking black, with the solutions of iron, differing in the degree of solubility, in different menstrua, and in the proportion of gum and resin. It constitutes the astringent and bitter quality in peruvian bark, it may be extracted from the leaves and bark of the Persimmon, galls yield it to a watery menstruum, in the proportion of four drachms to the ounce, and it may be obtained, in considerable quantities, from the common pig-nut.

"Morveau supposes the acid in astringents, is formed of this resin and pure air. The twelfth experiment clearly confutes this opinion, for the resin is there seen, in large transparent globules, when the iron, the ponderous earth, and the mercury were precipitated by the acid.

* Keir's Chemical Dictionary, article, acid of tartar and sugar.

"To succeed in this experiment, with galls, and other astringents, it is necessary to have a strong infusion of them, for it does not take place, after the resin has been extracted by one or two infusions, altho' the astringency remains.

"The precipitate formed, by adding the alkalies, to vegetable astringents, has been mistaken by some authors for the astringent principle. In Keir's chemical Dictionary, and in the last edition of the Encyclopædia Brittanica, a number of observations may be seen, relating to this principle. It is there said, when redissolved in water, it blackened a solution of vitriol but faintly, and in no other manner, than what arose, from a small quantity of acid remaining, which is proved it contains by distilling it. The author of these observations has been mistaken, and it is not a difficult matter, to point out in what manner he has been deceived. The astringent taste arose from a quantity of acid, which he acknowledges it contains, its solubility in water, arose from the same cause, for after it is several times washed, and the water filtered, it does not blacken a solution of vitriol, but when diffused in water, and added to a solution of that salt, the color is immediately changed, for its solubility in water, like alum and the calcareous phosphat of urine, is owing to a superabundant acid.

"When spread with a feather, over an ancient, decayed writing, it restored the legibility of the letters. Various methods have been recommended, by different authors, for this purpose; among others, the distilled liquor of galls, in Caneparious's collection de atramentis, and the phlogisticated alkali, by Dr. Blagden, in the Philosophical transactions, for the year, 1787. The unripe juice of the Persimmon, possesses two advantages over these fluids; it is a more powerful test for detecting the presence of iron, and forms a gummy resinous coat over the letters, defending them forever, against the action of air and moisture.

"The matter formed by the junction of the astringent juice and steel filings, and the precipitated fæcula of green vitriol, possesses the same properties.

"The twelfth, and following experiments, naturally lead us to say a few words, on the changes which take place, in the precipitates of iron, by the vegetable astringents.

"On this subject, Messieurs Macquer, Monnet, Gianotti and the academicians of Dijon, have been particularly engaged. The two former, and the greater part of chemists, consider the precipitate of ink, to be united with a principle in the gall-nut, in an oily state. Mr. Gianotti thought, that the iron was united

with the astringent principle; and that it was in the state of a neutral salt. The gentlemen of the academy of Dijon, suppose the astringents direct their action to the vitriolic acid, and precipitate the iron pure.

"My experiments have induced me to draw a different conclusion, from those gentlemen. I have clearly proved, that a neutral salt exists readily formed in astringent vegetables, composed of a peculiar acid and the earth of alum, independent of a resin, which most of them contain.

"In the making of ink then, a double elective attraction takes place; the gallic acid unites with the iron of green vitriol, while the vitriolic acid unites with the earth of alum. In an acid solution of green vitriol, no precipitate happens, because the vitriolic dissolves the iron as salt, as it is precipitated; but, if a sufficient quantity of an alkali is added, to saturate the vitriolic acid, the precipitate remains suspended in the liquor; still continue to add the alkali, and you saturate both the gallic and the vitriolic acid, and the iron is precipitated, of a dirty color.

"This theory points out the necessity of having a vitriol, exactly saturated with acid, in the making of ink: the propriety of adding a small quantity of the vegetable alkali or

steel filings, to the common ink powder of the shops, and the improper practice which some people have, of using vinegar as a menstruum, to extract its virtues.

"It shows the propriety of Mr. Clegg's proposal, for employing vegetable alkali, as a substitute for verdigise in the black dye, for which he received a silver medal and ten guineas, from a society instituted in London, for the encouragement of arts and manufacturers, in the year 1783.

"It accounts for the phenomena, which happened in a number of experiments made by Drs. Skeets and Irwin, in which magnesia, lime, chalk and the alkalies were triturated with peruvian bark, and added to a solution of green vitriol; and which Irwin accounted for, by supposing the presence of fixed air.

"The fallacy, of triturating astringent gum resins, with different substances, and adding them to a solution of green vitriol, and making the intensity of the color struck, a proof of the strength of the solvent power, is here pointed out.

"It explains the reason, why in the precipitates of iron by the nut-gall, the coalition of particles is successive, and remains suspended in the fluid, and why in the uva ursi, the pig-nut, and the Persimmon, they concrete together,

in large particles, and fall to the bottom of the vessel. In the first case, the resin being contained in a small quantity, and united to a portion of the acid, is readily soluble in water; in the second case, the resin is contained in a large proportion, and is insoluble in water.

"It likewise explains to us the cause of increased blackness of ink, in the common practice which school boys have of adding chalk, lime, &c., to the fluid.

"The doctrine of astringents, serves as a key to many of the experiments of Dr. Percival, and accounts for the manner in which acids neutralize astringents; by destroying the affinity between gallic acid, and the earth of alum.

"In short, it simplifies the Materia Medica, it is an interesting addition of chemistry, and in future it is probable, the whole catalogue of astringents will yield to one or two of the most powerful, and the author queries, whether even the peruvian bark, will not give place, to the more powerful combination, of galls and gentian, or the Persimmon and centaury.

"The acid of galls, forming an ink with green vitriol, may be offered as an objection to this theory, and it may be asked, why does not the vitriolic acid, in this case, dissolve the iron? The answer to this question is easy, the vitriolic acid is too weak to act on the

iron, and an ink made in this manner, though at first of a deep black colour, yet is not durable."

After describing the resin or rather the method of getting it for pharmaceutical purposes, Woodhouse discusses its efficacy in medicine for fevers, for hemorrhoids, for dysentery, for diabetes, for "spungy, swelled gums and loose teeth," for "stone in the urinary passages," and for chronic ulcers, indicating also its use in the arts under the following heads:

1. In the Tanning of Leather

"The greater the quantity of resin contained in any vegetable astringent, the greater the ease with which the leather may be impregnated with it, and its greater degree of insolubility in water afterwards, so much the more valuable is it, in this important branch of manufacturers.

"The use of tanning, says Dr. Macbride, is to prevent the leather from rotting, and to render it impervious to water. Any astringent vegetable substance, is powerful enough to accomplish the first purpose, but to render the leather impervious to water, requires one containing a large proportion of gummy resinous matter.

"The superiority of oak bark over other astringents, is owing to this property. The famous essence of this substance, is no more than an extract made by infusion, and was first proposed as a substitute for oak bark, in a memoir delivered to the Bath Society, in the year 1773.

"The unripe juice of the Persimmon, provided it could be obtained in sufficient quantities, and for a price which would not greatly enhance the value of leather, must be preferable to oak bark, for reasons evident to every chemical mind.

"Allowing every tree to produce four bushels of fruit, though Mr. Bartram says, he has seen some which produce six, and suppose three hundred of these trees cultivated; the quantity of gum resin which would be produced, would be 1800 pounds, as I have ascertained by experiment, computing six pounds to a tree. The quantity of juice would be several hundred gallons, which might be kept in barrels till wanted for use.

"North Carolina is the only state, in which the Persimmon is cultivated; it is a common practice there to ingraft it on the apple, by which means the rapidity of its growth is greatly increased.

"When we oppose the cleanliness of the

process, if the Persimmon could be used, the strength of the astringent, the small number of hands required, the small capital to begin and little labour requisite to carry on the business, the trifling piece of ground which a tan-yard would occupy, the value of the leather and shortness of time necessary to finish it; to the large capital at present required, the number of hands employed, the quantity of labour, the immense loads of bark, the annual expense of a horse and price of instruments to grind it, and the length of time necessary to finish the leather, we may conclude, the experiment is well worthy the attention of some philosophical tanner.

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2. As an Ingredient in the Black Dye

"The black dye in common use, is no more than an ink, made by adding a vegetable astringent to a solution of green vitriol, altho' realgar, antimony, litharge, arsenic, orpiment and other substances have been added to the ingredients.

"In the Swedish transactions for the year 1753, a fine black is said to be dyed, with the leaves of the uva ursi, the black matter concretes together in large particles, which is supposed to be of great advantage to the black

dye, as the largeness of the colouring particles, which concrete in the pores of the cloth, may render them more fixed, consequently less of the colouring matter is wasted in the liquor. To this cause, says Dr. Lewis, may be attributed a quality of the uva ursi dye, mentioned by the Swedish author, that the cloth is cleaner, than after the other black dyes, or requires less washing to free it from the loose colour.

"The juice of the Persimmon, precipitates iron in the same manner as the uva ursi, in large particles, which fall to the bottom of the vessel. I have dyed silk with an ink made of this substance, which was as black, and bore washing as well, as that dyed with galls, logwood, and fifty other ingredients.

"It is astonishing to think, an exorbitant price is still paid for galls and logwood, when bushels of a substitute superior to either, may be had for the trouble of carrying them away.

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3. In the Making of Ink

"The great defect in an ink, made from the juice of the Persimmon, is that, the precipitated iron, concretes together in large particles, and falls to the bottom of the vessel; this takes place in a greater or less degree, in every precipitate of iron, by a vegetable

astringent. In some inks this circumstance may be prevented by the addition of gum arabic, and the colouring matter kept suspended in the fluid; I have attempted it in vain, in ink made from the Persimmon, the letters always appearing as if written by charcoal diffused in water. An ink has likewise been made from the precipitated iron mixed with water, and kept suspended by the addition of gum arabic; when made in this manner, tho' it is durable, yet the letters may be washed off from the paper as easily as if written with any black powder diffused in water.

"In the latter end of October, and in Novemver, the astringent gum of the Persimmon, is converted into a sweet nutritious substance, which remains on the trees 'till January, and serves as food to squirrels, rabbits, raccoons, and other animals.

"The manner in which this change is produced, would lead to an inquiry, as curious as it would be useful. It appears to be a process, analogous to a mortification in the extremities of the human body, and brought on by the same cause. An extinction of life, from a languid circulation, caused by the debilitating power of cold. In what manner this quality acts, in producing a decomposition, is difficult to determine: the constituent

principles appear not to be changed, they are only modified; the gum resin is principally composed of acid, oil, earth and water: the ripe fruit contains the same principles, and even when changed into a vinous liquor and distilled, the composition is still acid, oil, and water. Here we must rest satisfied with the fact, for it is not the business of Chemistry, to wander in the boundless regions of conjecture. Perhaps some future experiments, may throw light on this mysterious process, which at present only proves, that nature herself is a great Chemist.

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4. To Make Spirit of the Persimmon

"For this purpose a certain quantity of water is to be added to the Persimmon when ripe, and the whole put into a proper vessel to which a certain quantity of yeast is to be added, to promote a fermentation. Every bushel of fruit treated in this manner, will yield one gallon of spirit, of an agreeable flavour. If beer is preferred to spirit, the fruit boiled in water, which is afterwards strained, and set to ferment; hops are then added to prevent the fermentation from proceeding too far, and it is bottled for use.

"Those who would wish to collect large

quantities of the fruit for distillation, may consult a memoir published by Mr. Bartram, in the first volume of the American Philosophical Transactions."

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5. To Make Persimmon Bread

"When freed from the stones, they are to be mixed with flour as potatoes generally are and baked in the same manner. Bread when made in this way, is not only very nutritious, but has the advantage of economy to recommend it."

The very critical person will doubtless have smiled on perusing this maiden production of Woodhouse—but the period, the general knowledge of chemical substances at the time, the state of our own country must be contemplated before hastily and testily consigning the dissertation to the waste-paper basket. It represents a beginning and, from the best information at hand, it was a most serious beginning. Let it then rather be viewed as a pioneer step and let the student of the present rejoice that as early as 1792 the spirit of research was abroad in the infant Republic and that men were striving to discover the truth. They gave themselves whole-heartedly to their pursuits.

One pauses on reading the contributions of the early alchemists and endeavors to put himself in their place and to recall their aims; but this is easier of accomplishment in the instance of Woodhouse's work, performed long after, but yet in a period still quite distant from the present—for it all occurred in the closing decade of the eighteenth century and in the beginning of the nineteenth century.

Shortly after graduation in medicine, Woodhouse (1792) conveyed a considerable portion of land in Northumberland County to his former preceptor for a very nominal sum. It would be interesting to know whether this was out of gratitude for the many kindnesses shown him by Dr. Rush, or whether it may have been in the nature of a fee for the preceptorial privileges enjoyed under his patron.

A copy of the deed follows. It was discovered among letters and documents of Rush mentioned on page 11.

"Know all men by these Presents, that I *James Woodhouse* for and in Consideration of the Sum of *five shillings* to me in hand, well and truly paid by *Dr. Benjamin Rush* the Receipt whereof I do hereby acknowledge; and for other good causes and valuable Considerations me thereunto moving, have granted, bargained, sold, released, assigned, conveyed, and confirmed, and by these Presents do grant, bargain, sell, release, assign, convey, and confirm unto *the said D^{r} Benj^{n} Rush* his Heirs, Executors,

Administrators and Assigns for ever, all my Right, Title, Interest, Property, Claim, and Demand whatsoever, of, in, and to a certain Warrant, by *me* obtained out of the Land office for the Commonwealth of Pennsylvania, bearing date for the Quantity of *four hundred* Acres of Land (*be they more or less*) *on the waters of Loyal Creek on North*^{d} *County — adjoining land granted April 9*th *1792 to James Mease* and likewise all my Right, Title, Interest, Property, Claim or Demand whatsoever, of, in, and to any Return that is or may be made on the said Warrant, or of, in, and to the Patent or any Part or Parcel of the said *four hundred* Acres of Land patent, located, surveyed, or to be patent, located, or surveyed, or held in Pursuance of the said warrant with all of the Appurtenances thereunto belonging, to the only proper Use and Behoof of the said *Doctor Benjamin Rush*—his Heirs, Executors, Administrators and Assigns for ever, under the Reservations to the Commonwealth of Pennsylvania due, or to become due, therefore and other Charges and Taxes on the said Warrant or Land, to be paid at the Cost and *Charge of the said Doctor Benjamin Rush*—his Executors, Administrators or Assigns: and I the said *James Woodhouse* for myself, my Heirs, Executors, and Administrators, shall and will at any and all time or times hereafter, upon the reasonable Request and Cost of the said *D*^{r} *Benjamin Rush*—his Heirs, Executors, or Assigns, make, do, and Execute, Acknowledge and Deliver or cause to be done all and every such further and other Conveyances and Assurances in the Law for the better granting and conveying the said Land and Premises with all the Appurtenances unto the said *D*^{r} *Benjamin Rush* Heirs, Executors, Administrators, or Assigns as by *his* Council learned in the Law shall be devised, advised, or required. IN WITNESS whereof

I have hereunto set my Hand and Seal, this *twenty-fifth* Day of *May* in the year of our Lord one Thousand Seven Hundred and *ninety two.*

Signed, Sealed
and delivered
in the Presance
of

JAMES WOODHOUSE

WARNER WASHINGTON JUN^R
JN^O F. HALL

Received the *25th* Day of *May* the Sum of *five shillings* being in full, for the consideration Money above mentioned.

Witness
JN^O F. STALL

JAMES WOODHOUSE

And on *the inside page of this deed,* there is written:

"For a valuable consideration which I hereby acknowledge to have received, I do hereby assign & transfer to Joseph Priestley Jun^r all my right, title, interest, claim & demand whatever to the anexed deed poll or instrument of writing. In testimony whereof I have hereunto set my hand & seal this 18 of February 1794.

BENJAMIN RUSH

Witnesses present
EDW^D FISHER
ABBY STOCKTON

On the 20^th day of February 1794 came before me Rob^t Martin Justice of peace in the county of North^d Dr. Benjamin Rush & acknowledged the above assign-

ment or transfer to be his Act, and deed & desired it might be recorded as such. Witness my hand & seal

ROB^{T} MARTIN

Joseph Priestley, Jr., came to America some years prior to the arrival of his father. He and other Englishmen had traversed considerable portions of the State of Pennsylvania in search of a site suitable for an English community—sufficiently removed from other pioneer settlements. Such a spot was found on the North branch of the Susquehanna River in Northumberland County, but in some mysterious way the scheme failed, and Priestley, the younger, sought a home for himself. The conveyance, just cited, shows clearly his final decision, and it was on that site that he later received his father, who, when in Philadelphia in 1794, showed such eagerness to reach Northumberland, conscious that a home was awaiting him there. Little did "the honest old heretic" realize or suspect that in this new home he would prosecute the cause of phlogiston on territory once owned by young Woodhouse who, in a few short years, was to become one of his most ardent opponents.

One wonders whether having become a medical doctor, yet possessed of such great love for

Chemistry, Woodhouse would devote himself to medical practice or to chemical pursuits. It has been said that "after his graduation he confined almost his entire attention to Chemistry." This seems correct, but he did do some medical work, for on March 16, 1792, he reported a case of Hydrocephalus in which he remarked:

"Future experiments and observations must determine, whether bleeding is preferable to the common method of treating the hydrocephalus . . . altho' there can be no doubt of the propriety of bleeding in preventing disease."

Again, on September 1, 1792, he wrote of the case of an infant of five years—that it was originally remitting fever "which terminated in hydrocephalus, proves the fallacy of the symptom of worms, and confirms the idea of Butler, that the worm fever of authors, is no other than the infantile remitting fever."

One of the popular agencies for the encouragement of chemical studies in the infancy of our Republic was the Chemical Society of Philadelphia. It enlisted the sympathies of a wide circle of specialists.

A great deal has been said regarding it.

It is certain that it was a very serious undertaking on the part of its supporters, that it promoted research in every possible way, encouraging its membership by all means in its power to have the Society become a vehicle of bringing to the country the latest and most useful information on chemical subjects.

It must have been a source of pride to Woodhouse, for he conceived it and was the real founder of the Society—the first Chemical Society in the world. Its stated meetings were held weekly in the Philadelphia Laboratory in Anatomical Hall. It was constantly advising the citizens of its desire and readiness to aid them and, therefore, requested that all objects requiring analysis should be promptly sent them. Annual lectures of considerable importance were delivered before it. In the address of one of its Vice-Presidents flattering reference is made to Woodhouse—its founder, its first and only President—in these words:

"I must notice . . . in our worthy President, that science has not only gained a strenuous vindicator of its doctrines, but also a liberal inquirer after truth, an elegant and successful experimenter."

In all this there is sufficient evidence that Chemistry claimed Woodhouse's serious thought. Presumably, he used medicine to obtain the

means necessary to prosecute his purely chemical studies. He was surely a devotee of the science, as indicated by his introductory words on facing an audience on one occasion:

"Let Miss Chemistry be your only mistress —the only object of your devotion and homage."

To revert, briefly, to the Chemical Society: There is abundant evidence that under the inspiring presidency of Woodhouse it made praiseworthy contributions and was most favorably regarded throughout the Republic. For example, the American Mineralogical Society (New York), modeled after the Chemical Society, announced that the older Society had "laudably set the example it hoped to imitate by soliciting information upon the resources of our Country" and that it was especially helpful in furnishing at least "one article of great national importance." In glancing through the publication (*The Weekly Magazine, 2* (1798), pp. 329 and 374) describing the article, the thought suggested itself that the contribution possessed an appropriateness for the reader of the present, when the chemists of our country are so largely engaged in caring for the national defence. Their representatives in the days of Woodhouse also, inspired by lofty patriotism, devoted themselves to the interests of the country, and we

can but admire their zeal and be grateful for their achievements, however humble their character. The Society had made a public request that "any person who may possess information relative to the manufacturing of nitre forward it to them." In answer to the inquiry there came this reply:

"In the present critical situation of our country few subjects claim a more serious attention than those which essentially contribute to its defence. We may erect fortifications and procure ordnance, but if we are not provided with ammunition our guns will be useless and our forts of little consequence. From these considerations a few hints on nitre, and the best means of manufacturing it in America may be offered.

"Nitre is well known to be the basis of gun-powder, a substance of indispensable necessity even in defensive war. At present we depend almost wholly upon foreign countries for this article: our navigation is already much impaired and if actual war should take place the difficulty of obtaining nitre would be encreased so greatly that it might not be possible to procure sufficient quantities from abroad to answer the immense expenditure which must necessarily ensue.

"Most governments have paid attention to

the sources from whence nitre may be obtained and in general their researches have been crowned with success. There is scarcely a part of the inhabited globe where this salt may not be made. In some countries it is collected with very little trouble or expence while in others much attention is necessary to procure it even at considerable cost and, as it has generally been managed, great inconvenience to the inhabitants. In England formerly and in France, now, the salt-petre makers have the power of entering the houses of the inhabitants, obliging them to suffer their stables and cellars to be dug up and the earth carried away for the use of the state.

"In India there are considerable districts of country abounding in nitre. The lixiviation of the soil, evaporation of the lixivium, and crystallization constitute the whole art of nitre-making; hence nitre can be brought ten thousand miles and sold at a price considerably below what it can be made for here. Lands possessing the same property are found in Spain and in South America; in France certain stones are discovered which by an easy process yield nitre in abundance. It is highly probable that lands impregnated with this salt exist in our own country; none such, it is true, have yet been discovered, at least

on this side the mountains; and it is perhaps equally true that the investigation has never been made with sufficient accuracy. But though there is reason to regret the want of energy in an enquiry so important to the public, and the success of which would at once set the discoverer beyond the reach of poverty, there still remains a source from which nitre may be procured in quantities sufficient to meet every exigency. This subject offers to men of enterprise and activity the most flattering prospects of wealth, and has, besides, the advantage of public utility combined with individual emolument: The simplicity of the process renders this source of riches accessible to men of the most moderate capacity, and its public utility ought to stimulate the patriotic. Most manufactories require an extensive capital to be employed or they cannot be carried on with advantage; but from this inconvenience the making of nitre is exempted. The few buildings necessary, are constructed with as little expence as the sheds of a brick-yard: the utensils are chiefly made of the cheapest materials, and the substances from which nitre is to be extracted cost little more than the trouble of collecting them.

"It is a fact well known to chymists that nitre is produced in great abundance by the

decomposition of animal and vegetable substances by putrefaction. The animal matters afford azotic gas in a fit state to combine with the oxygen of the atmosphere and produce nitric acid, while the decaying vegetables furnish potash with which the acid unites to form nitre. All that is necessary, therefore, is to collect a sufficient quantity of these materials and place them in circumstances favourable to the development of the principles from which nitre originates and when the salt is formed to extract it from the mass through which it is diffused.

"To make nitre with advantage no dependence is to be placed upon the scanty supply which stables and cellars afford and which cannot be procured without difficulty and ill-will. What are called nitre-beds are formed by digging a long and wide ditch in the earth, filling this ditch with putrefying animal and vegetable materials, and erecting a shed over them which must be left open at the sides that the air may have free access. The vicinity of larger cities is the proper place to construct nitre-beds for here the supply of materials is inexhaustible. The sweepings of the streets, the rubbish of old buildings, the cleanings of cellars, and the refuse vegetables, of Philadelphia for instance, would furnish more nitre-

beds than there are now brick-yards. When the beds are formed they are to be watered from time to time with the most putrid water in the neighborhood and of which in the environs of cities there is seldom a scarcity, and stirred occasionally to expose fresh surfaces to the air. To judge when the bed is sufficiently impregnated with salt to be worked with advantage a small quantity, the weight of which must be ascertained, is lixiviated and the salt obtained by evaporation and crystallization. The weight of the salt compared with that of the compost from which it was procured determines the question.

"Having decided on the propriety of proceeding to extract the nitre, a number of large tubs, similar to those used by soap-boilers, must be procured each of which should have a hole in the bottom stopt by a plug. Some sticks must be spread on the bottom of each tub and a little loose straw thrown over them. The nitrous earth must then be put in so as to fill about two-thirds of each, and a stratum of wood-ashes and lime in the quantity of one fourth of the whole mass laid at top: boiling water is then to be poured on till the tubs are full. The water should remain twenty-four hours and the mixture stirred from time to time, after which the plug is to be taken out and the ley drawn off.

"The ley thus obtained requires to be clarified, which is done by mixing some blood or eggs with it and gently boiling. The impurities will be entangled with the blood, which coagulates by heat, and will rise to the top in a thick scum, which must be carefully taken off. After the fluid is thus prepared it must be put into boilers, which for convenience may be fixed in brick work as in pot-ash manufactories, and evaporated until a drop let fall on any cold substance, becomes solid: it is now to be poured into large earthen pans and set in a cool cellar to shoot. At the end of two days, or sooner, a great number of crystals will be formed which will be of a brownish colour and very impure owing to a mixture of sea-salt, several salts with earthy bases and some extractive matter: this is called nitre of the first boiling, to purify which it must be dissolved in clean water, evaporated and crystalized as before; and the same process repeated a third time. Nitre of the third boiling is not absolutely pure, but it is sufficiently so for the making of gun-powder, and most other purposes: it is only for some nice chemical experiments and in medicine that greater purity is required and this may be obtained by repeating the solutions and crystalizations.

"It is to be observed that all the salt is not

extracted from the materials by the first water: a second quantity is therefore to be poured on and, after remaining a day, drawn off as at first. This ley is not sufficiently strong to be evaporated with profit but is used instead of simple water to extract the salt from fresh materials; and the fluid that remains in the pans after the first crystalization contains a great deal of nitre which may be obtained by further evaporation and cooling."

In 1769 there appeared an article from the pen of Dr. Percival "On Bitters and Astringents." It passed through four editions and was translated into foreign languages. Several chemists had essayed to "controvert some of the principles" set forth by Dr. Percival, and Woodhouse, being deeply interested in the facts set forth by Percival but differing radically from him issued "Observations on the Combination of Acids, Bitters and Astringents" in 1793, in which, declaring his sole "object, the establishment of the truth" he wrote thus:

"Dr. Percival . . . having infused a quantity of powdered Peruvian bark in vinegar and water, and added some of the infusion to a chalybeate solution, he found at first no change of colour take place, though in a few minutes a slight black tinge appeared.

"The result of this experiment, induced him to make further trials of the effects of acids on vegetable astringents, and having added some white wine vinegar to an infusion of chamomile flowers, and a triturated infusion of the bark, and added these infusions to a solution of *sal martis*, he found no change of colour produced. Afterwards having made ink, with an infusion of galls, and a solution of *sal martis*, he discharged the black colour by the acid of vitriol, and then restored the original blackness with the spirit of hartshorne.

"From these experiments he supposed an affinity between acids, bitters and astringents, and this suggested to him an idea, that they might possibly neutralize each other, and form what the chymists call a tertium quid. This point he attempted to ascertain by adding vinegar to infusions of the bark, Aleppo galls and gentian, and concluded from his experiments, that acids, bitters and astringents neutralize each other.

"Having given this summary of the experiments of Dr. Percival, I shall

"1. Take notice of the best method of discovering an astringent quality in vegetables.

"2. Shew that change which takes place, upon adding a vegetable astringent to a solution of green vitriol.

"3. Point out the manner in which the doctor was deceived, and

"4. Relate several decisive experiments, in which mineral and vegetable acids, were added to bitters, and astringents.

"1. The property of striking a black colour with a solution of green vitriol, has long been regarded as an indubitable test of astringency, but as this is owing to the gallic acid uniting with the iron of the green vitriol, as many vegetables contain this acid, which are not astringent, as the black colour produced is not in proportion to the astringency, as it *does not happen* when the astringency is *not destroyed* by the acids, and it takes *place* when the astringent principle is *completely destroyed* by magnesia or the alkalies, it follows that the property by which vegetables strike a black colour, with a solution of green vitriol, cannot be considered as a proof of their astringency.

. . . . .

"2. Upon adding a vegetable astringent to a solution of *sal martis*, a black colour is produced.

"There have been many different explanations of this fact; the opinion to which Dr. Percival seems to have adhered, is that the astringent principle was united to the iron of the green vitriol.

. . . . .

"3. Dr. Percival was deceived, first, from using a fallacious test of astringency, secondly, from being under the influence of a preconceived opinion, and thirdly, from being ignorant of that change which takes place, upon adding a vegetable astringent to a solution of *sal martis*. As he thought he had proved, that acids neutralize astringents, so when he added the vitriolic acid, to a decoction of galls and a solution of *sal martis*, he supposed the acid neutralized the astringent principle, whereas, it only dissolved the ferrugenious particles, that this is actually the case may be proved by adding the pure gallic acid, which is *not astringent*, to a solution of green vitriol, and then discharging the black colour, by dissolving the precipitate, with the vitriolic or marine acid.

"4. I shall relate a few experiments, in which mineral and vegetable acids, were added to bitters and astringents, and take notice of the result.

Experiment I.

"Different portions of the vitriolic, nitrous and marine acids, vinegar and lime juice, were separately added to solutions of gentian, chamomile flowers and columbo root; the bitter principle always predominated to the

taste, a piece of paper stained blue, was in every instance turned to a red colour.

Experiment II.

"Different portions of the vitriolic, nitrous, marine acids, vinegar and lime juice, were separately added to solutions of galls, Spanish oak and Peruvian bark; in no one instance was the astringent principle neutralized; the solution of galls was more pleasant to the taste, the astringency of the oak bark appeared to be increased; upon adding the vegetable alkali to it, a more copious precipitation took place, than from the watery solution alone.

Experiment III.

"Alum added to a solution of galls and Spanish oak bark, caused a precipitate, partly insoluble in the vitriolic acid.

"This experiment was suggested by reading an essay intitled 'Consideration in different materials as objects of the art of dyeing'; by Mr. Henry, published in the third volume of the Manchester memoirs, wherein he asserts a complete decomposition of alum takes place when added to a solution of galls, which is by no means the case, as the alum may be obtained by chrystallization after the addition.

"The insoluble precipitate is the resin of the

galls, which may be thrown down, by using a solution of columbo root, instead of alum, but which will not take place with chamomile flowers or gentian, or by adding the alum to a solution of Peruvian bark.

"The frequent opportunities Dr. Percival had of observing the effects, arising from a combination of green vitriol and astringents, naturally led him to examine into the principles of ink, and from a number of fallacious experiments, he was led to differ materially from Dr. Lewis, who has paid particular attention to this subject.

"Having immersed a piece of polished iron, into a cold infusion of the Peruvian bark, made with distilled water, he found the liquor in three hours just preceptibly tinged black; while the same piece of iron wiped clean, and immersed in another infusion of the cortex, made with common spring water, in less time gave a deep purple colour to the liquor.

"The spring water employed, he tells us, contained a considerable portion of selenitic salt, and hence, by dissolving the iron immersed in it, formed a perfect *sal martis*, from which he inferred an acid is essentially necessary in the formation of ink, and having afterwards prosecuted the subject, concluded 'whatever deprives green vitriol of its acid, whether it be

heat, the addition of an alkali, or repeated *affusions of water*, destroys its power of striking a black colour, with vegetable astringents.'

"The experiments detailed by the Doctor, by no means justify this conclusion; he did not attempt to make ink, with a *calx of iron*, precipitated from green vitriol by an *alkali*, and it clearly appears it made use of the earth, which never fails to be mixed with green vitriol, in the decomposition of the *pyrites* instead of a *calx of iron*, and which separates from it by solution in water, in the form of a yellow ochre, or he never would have thought of depriving green vitriol of its acid, by 'repeated affusions of water.'

"To put this matter beyond a doubt:

Experiment IV.

"A quantity of the calx of iron, thrown down from green vitriol by the vegetable alkali, being several times washed, until the water was insipid to the taste, and produced no further precipitation upon the addition of an alkali, when added to a solution of galls, produced an ink, equal to that made with common green vitriol.

"Having thus taken a summary of part, and the most important part, of the essay on bitters and astringents, pointed out the taste

as the least fallacious test of astringency, shewn the manner in which Dr. Percival was deceived, and confuted him in several particulars, we may conclude:

"1. Acids and bitters do not neutralize each other.

"2. Acids by a superior affinity to the base of the astringent principle, by detaching the gallic acid, decompose, but do not neutralize astringents, forming *salts* or *saline gums* of different degrees of astringency, according to the acids employed.

"The astringency of the oak bark was increased by the vitriolic acid, because it contains a large proportion of earth unsaturated by the gallic acid, hence the copious precipitation, upon the addition of the alkali, after adding the vitriolic acid.

"By spontaneous evaporation in the open air, an acid salt is produced, and during the chrystallization, *micaceous spangles*, resembling drops of tar thrown into water, appear swimming on the surface of the fluid.

"The bark of an oak tree may be considered as a coat of pure argillacious earth; to prove this, let a small quantity of the ashes which falls upon a log of wood, after the combustion of the bark be collected, and they will be found insipid to the taste, upon adding weak vitriolic

acid once or twice, and washing the mixture in water, the *phlogistic* matter will be destroyed, and the pure white earth may be obtained, mixed with a small proportion of silex. Alum in this case will not be formed, as the solution will not take place in the cold.

"The *argillacious* earth which is found in common ashes, comes principally from the bark, the vegetable alkali, from the body of the wood, though no doubt in the latter case, argill and silex may be obtained, but in no proportion to the vast quantities contained in the bark.

"3. The vitriolic acid, according to the opinion of Dr. Lewis, and contrary to the opinion of Dr. Percival, is not necessary in the formation of ink."

That Woodhouse in no wise considered himself infallible is seen from the following lines: "The author . . . has but one object, the establishment of truth; as he has made free with the opinions of his predecessors, he wishes his own may be diligently scrutinized, for he is as equally liable to be deceived, as others of his Medical brethren."

The monotony of medical practice may have irked Woodhouse as it has others who have

come through medicine to chemistry. It was, however, the only course open in those days to chemical aspirants. Thousands since have pursued this course. Many chemists, too, have come through pharmaceutical training to chemistry and have made their presence as teachers and investigators very appreciably felt. However, the day of Woodhouse's release from his distasteful pursuits was rapidly approaching; indeed, how it all came about may now be set forth; but before narrating the manner in which the change occurred it may not be out of place to introduce a few facts, even though a bit remote to the subject. First, it was said in after life by Silliman and again by Rush that Woodhouse was an infidel, an atheist. If this was true it was probably due to his environment. Let us not forget that the year 1793 was the most eventful one during the decade. Citizen Genet had just arrived in Philadelphia accompanied by numerous followers. The saturnalia of license and revelry, which ensued, surpassed anything similar witnessed in the City of Brotherly Love before or since. Several thousand French refugees came shortly thereafter from San Domingo. And it has been asserted that from the moment the notorious Genet and his admirers entered the home city of Woodhouse on May 16, 1793,

pandemonium broke loose. He was welcomed by prominent citizens, fêted at the State House and overwhelmed with extravagant attentions on all sides. Soon Philadelphia became infected with the Gallic craze. . . . French names and customs prevailed . . . the vices of the Latin became firmly seated in the city on the Delaware. The newspapers were filled with French advertisements—dancing schools, French lessons, fencing academies, pastry shops, French brandy, etc. Children were instructed in the wild dance and French song known as the Carmagnola, etc. Even the staid, thrifty business and professional men were swept from their feet and fell into conduct and views diametrically opposed to their strict Colonial teaching. It is not improbable that Woodhouse yielded to the spirit of the day and may have carried through life some of the ideas then absorbed.

But the tragic feature of the year 1793 must not be forgotten. This was nothing less than the fearful visitation of yellow fever—that deadly scourge which carried away by death 5,000 souls from August 1st until November 9th. It was then that mourners went about the streets—friend after friend having been stricken with the fearful malady, and people scarcely dared meet to pray together—when doctors

were dead—nurses fled—the poor neglected; but Woodhouse remained, heroically supporting his chief, Rush, and performing his duty amidst surroundings which literally tried men's souls. It was a magnificent exhibition of his sturdy, unselfish character. And it was of this man that it was said, "his opinions and conduct were regulated by Rochefoucault's maxims—an open and rude infidel."

But to return to the immediate subject, and his promotion. It was also in 1793 that James Hutchinson, Professor of Chemistry in the Medical School of the University of Pennsylvania, died, and on Tuesday, January 7, 1794, Dr. John Carson was chosen his successor. Unfortunately, before he could deliver a lecture the Grim Messenger summoned him hence.

On June 4, 1794, the renowned Priestley arrived in New York. Upon his landing he was welcomed by many distinguished persons. He received addresses from learned societies, among them the ancient American Philosophical Society, and on his arrival in Philadelphia, he was greeted with the greatest cordiality. Priestley himself said, "My reception is too flattering, no form of respect being omitted. I have received formal addresses; more, they say, are coming; and almost every person of the least consequence in the place has been,

or is coming, to call upon me." And, again: "Whether it be the effect of liberty or some other cause, I find more clever men, capable of conversing with propriety and fluency on all subjects relating to government than I have met with anywhere in England."

So favorably impressed with Priestley were the Trustees of the University of Pennsylvania that a minute of the Board for November 11, 1794, reads:

"The Board, according to order proceeded to the election of a Professor of Chemistry in the room of Dr. John Carson, Deceased, when the ballots being taken and counted, it appeared that Dr. Joseph Priestley was unanimously elected."

In the Memoirs of Priestley (p. 167) it is stated that this professorship "would probably have yielded him 3000 dollars per annum, there being generally about 200 students in Medicine of whom about 150 attend the Chemical lectures . . . but he thought that if he undertook the duties of a professor, he should not be so much at liberty to follow his favorite pursuits . . . but what had greater weight with him than anything else was that my mother, who had been harrassed in her mind ever since the riots in Birmingham, thought that by living in the country, at a distance

from the cities, she should be more likely to obtain that quiet of which she stood so much in need." This quotation explains the following minute of the Trustees for March 3, 1795:

"Mr. Chief Justice (McKean) informed the Board that Dr. Joseph Priestley had declined the Professorship of Chemistry, to which he was elected in this institution the 11th of November last."

Whereupon Rush, solicitous for his protégé and eager that he should have the advantages accruing from so important a position, promptly indited the following letter:

To the Trustees of the University of Pennsylvania.

GENTLEMEN:

The bearer, Dr. James Woodhouse, was my pupil for four years, during which he employed much of his time in chemical research and experiments. He has since devoted himself with great ardour to the study of Chemistry. From his talents, industry and knowledge, I believe him to be amply qualified to fill the Chemical Chair in the University of Pennsylvania. BENJAMIN RUSH

May 20, 1795.

This cordial recommendation is of more than passing interest in the light of the following letter addressed by Rush to his friend John Redman Coxe on November 4, 1794:

". . . Dr. Carson died a few days ago. The Professorship of Chemistry will be offered to Dr. Priestley. What say you to qualifying yourself to succeed him?

His (Priestley's) age will prevent his discharging the duties of that Chair more than eight or nine years. . . ."

Coxe, at the time, was in London and Rush did not anticipate a declination on the part of Priestley, so when this came he seized upon his favorite pupil as a suitable candidate for the vacancy, as it was evidently his purpose to place a friend in the position. Hence the election of Woodhouse on Tuesday, July 7, 1795, in the room of Joseph Priestley must have gratified him immensely, for he was quick to write again to Coxe:

PHILAD^A July 18^th 1795

MY DEAR FRIEND:

I have great pleasure in informing you that Dr. Woodhouse is elected Professor of Chemistry in our University. The votes were 10 in his favor 6 for Barton & one for D^r Ross (?). The appointment gives great pleasure to all the students of medicine. To me it is a cordial. His conduct as my pupil, and above all, his kindness, humanity, sympathy, & services to me during the glowing autumn of 1793 had endeared him to me in a high degree. In soliciting votes for him I told some of the trustees, that I was only paying a debt of gratitude I owed him. I have only to add that I wish in the Course of my life I may have it in my power to acknowledge my obligations as forcibly & successfully to you & W^m Fisher—D^r Woodhouse has entered upon his preparatory studies for his course with great spirit. His laboratory is already clear and in order. I have no fears for his success and reputation. He has genius, industry, knowledge & great steadi-

ness of Character — Barton is sorely mortified. He was so sure of the appointment that he sat at the feet of the Stairs of the university while the election was held, ready to receive notice of it. Poor fellow! He is much to be pitied. His talents, directed by principle and industry, would have made him respectable. . . .

Whereupon Coxe wrote in the following vein:

LONDON, September 5, 1795

DEAREST SIR:

. . . .

I was much rejoiced by a letter from M^r^ Fisher a few days ago—to find that Dr. Woodhouse has gained the Chemical Chair exclusive of his abilities etc. which will render his Professorship so beneficial; I was not a little pleased with the disappointment and chagrin of the ——— in being unable to establish their candidate in that situation.

——— ———

———

Woodhouse's election ushered him into a goodly company of distinguished men who constituted the faculty of the Medical School at the time. They had all attained the highest rank in their several specialties and enjoyed a world-wide reputation. They were also his seniors in years. However, his course among them, during the period of his activity won their confidence and admiration. It was not long until he was intrusted with the deanship

of the School. All his duties were discharged with the greatest care. Students, also, came to know him well and gave him their confidence. Many of their inaugural theses were dedicated to him. Among these was a rather notable contribution "On the Medical and Chemical Properties of Tobacco," the author of which said in his dedicatory lines, besides other things,

> Suffer me at the same time to declare that a grateful remembrance of the many favors you have conferred will be ever retained by
>
> Yr. affectionate friend,
>
> EDWARD BRAILSFORD.

John Gough likewise dedicated his thesis "On Cantharides, etc.," to Woodhouse, and besides the friendly acknowledgment of assistance took particular pains to announce that "Dr. Woodhouse has discovered two other species of this fly."

Further, Joseph Klapp of Albany wrote:

> "To you this imperfect essay is dedicated not with the vain expectation of giving fame to a reputation already established, but solely for the purpose of expressing my thanks for the friendly attention which you have bestowed upon me while in this city; and the high sentiments which I shall ever cherish for your unrivalled talents as an able instructor and scientific chemist."

Robert M. Patterson, Professor of Chemistry

in the College of the University, Vice-Provost of the latter, and subsequently Director of the U. S. Mint, attended Dr. Woodhouse's course in Chemistry, and said, "It was there I acquired my taste for this science."

Additional proofs could be offered, showing clearly the esteem in which he was held.

In 1796, Woodhouse was elected to membership in the American Philosophical Society, and was active in its affairs until his death, serving at various times as secretary and councillor. On one occasion he was chosen annual orator, and at another meeting, upon request of the Society, repeated a series of experiments in connection with a communication presented by E. J. Dupont de Nemours, "On the utility of the oxygenated muriatic acid gas in recovering animals from asphyxia."

Despite his evident interest in the proceedings of the Society, much of his thought, energy and time were given to the Chemical Society of Philadelphia, which was, so far as can be ascertained, his own child. It was in its meetings that most of his communications were probably made and discussed.

It is exasperating to the student of the history of Chemistry in this country that more cannot be learned about this pioneer Society. The fragmentary items discovered from time

to time become fairly tantalizing. It can only be hoped that by creating a live interest in the early Chemistry of Philadelphia someone may be imbued with a spirit strong enough to search out the old nooks and corners in neglected libraries—private and public—in this quest.

But, to leave this digression and return again to the fall of 1795, following close upon Woodhouse's elevation to such a dignified and important post, interesting comments will be noted. He was, as previously mentioned, the particular choice of Rush. His opponent or competitor was the very able, competent Adam Seybert, whom Wistar strenuously sought to have elected, but he was even set aside for Barton. The personal feeling of antagonism between Rush and Wistar was very marked. They were almost open enemies, hence Woodhouse's selection gave the followers of Rush unfeigned delight.

As to Adam Seybert it should be mentioned that he was one of the very first Americans to enjoy a training in the School of Mines of Paris in the closing years of the eighteenth century. He was a skilful chemist, especially along analytical lines. It was he, who, early in eighteen hundred, performed the office of his great namesake in the Garden of Eden, by

naming the few minerals, then forming the collection of Yale College, when submitted to him by Silliman, the elder.

It has been averred that neither Rush nor Wistar felt any special regard for his chosen candidate, except from the consideration that he would be his own retainer, and, as such, would aid in giving him party strength in the institution. The respective claims of the two candidates having been vigorously pushed for several weeks, the day of the election at length arrived, the vote was taken, and, as mentioned before, Woodhouse was chosen, though Seybert was, at the time, the more experienced chemist.

A graphic account of the course pursued by Woodhouse, close upon his election, is given in the autobiography of Dr. Charles Caldwell. The latter was an adherent of Rush. He was also plainly an egotist and a captious critic. Nevertheless, the picture he has handed to posterity, relative to Woodhouse and the career opened before him, is very readable and also illuminating. It reads:

"Upon the appointment of Dr. Woodhouse to the professorship at the University of Pennsylvania, he began immediately to prepare himself for the duties of his new and promising career. He became, in a short time, so expert and successful an experimenter, as to receive

from Dr. Priestley, who had just arrived in the United States, very flattering comments on his dexterity and skill. That distinguished gentleman, on seeing him engaged in the business of his laboratory, did not hesitate to pronounce him equal, as an experimenter, to anyone he had seen in either England or France. . . . At times, his devotion to chemistry and the labor he sustained in the cultivation of it were perfectly marvelous—not to say preternatural. . . . During an entire summer, (one of the hottest I have ever experienced) he literally lived in his laboratory, and clung to his experiments with an enthusiasm and persistency which at length threw him into a paroxysm of mental derangement, marked by the most extravagant hallucinations and fancies. He even believed, and on one occasion, proclaimed, in a company of ladies and gentlemen, that, by chemical agency alone, he could produce a human being.

"The special object of his experiments at that time was the decomposition and recomposition of water. The agent employed in his processes was of course caloric. And no alchymist in pursuit of the alcahest, or the philosopher's stone, ever labored in his vocation with a wilder enthusiasm, a more sublimated intensity, or a perseverance more stubborn,

than he did, immersed in a temperature intolerable to any human being possessed of natural and healthful sensibility.

"As already mentioned the weather was almost unprecedently hot; and his laboratory was in sundry places perpetually glowing with blazing charcoal, and red-hot furnaces, crucibles, and gun-barrels, and often bathed in every portion of it with the steam of boiling water. Rarely, during the day, was the temperature of this atmosphere lower than from 110° to 115° of Fahrenheit—at times, perhaps, even higher.

"Almost daily did I visit the professor in that salamander's home, and uniformly found him in the same condition—stripped to his shirt and summer pantaloons, his collar unbuttoned, his sleeves rolled up above his elbows, the sweat streaming copiously down his face and person, and his whole vesture dripping wet with the same fluid. He, himself, moreover, being always engaged in either actually performing or closely watching and superintending his processes, was stationed for the most part in or near to one of the hottest spots in his laboratory.

"My salutation to him on entering his semi-Phlegethon of heat not infrequently was: 'Good God, Doctor, how can you bear to remain so

constantly in so hot a room? It is a perfect purgatory.' To this half interrogatory, half exclamation, the reply received was usually to the same purport. 'Hot, sir—hot! do you call this a hot room? Why, sir, it is one of the coolest rooms in Philadelphia. Exhalation, sir, is the most cooling process. And do you not see how the sweat exhales from my body, and carries off all the caloric? Do you not know, sir, that by exhalation, ice can be produced under the sun of the hottest climates?'

"Such was the professor's doctrine; nor have I the slightest doubt of his belief in its correctness. So deep is the hallucination in which alchemy first, and afterwards chemistry, its lineal descendant, have, in many cases, involved the minds of their votaries and rendered them permanently wild and visionary in their actions. It is not, I think, to be doubted that alchemy and chemistry have deranged a greater number of intellects than all the other branches of science united. Even at the present day it is hardly short of lunacy to contend, as many chemists do, that chemical and vital forces are identical."

Another contemporary wrote: "Woodhouse went to work with a zeal and delivered a course of lectures with great applause; and as almost

the whole of his time was devoted to the study of his favorite science, he added to the number, variety, and brilliancy of his experiments."

Again:

"Nor is it aught but justice to him to say, that his improvement in the science he was destined to teach was signally rapid. He became so expert and successful as an experimenter as to receive very flattering compliments, on all sides, on his dexterity and skill. For Chemistry, he retained until his death, a predilection and fondness which were denominated with sufficient aptitude, in technical language, his 'elective attraction.' To everything but experimental chemistry he became comparatively dull and indifferent."

"His lectures," adds a third, "were replete with a number of brilliant experiments and were received with great applause."

Knowing that the eyes of the scientific world of America were upon him, Woodhouse attacked his problems with energy. He was well launched upon his real academic career, and during the short fourteen years of its continuance, accomplished vastly more than even many moderns are able to achieve with all their up-to-date conveniences.

The petty annoyances, arising at times among

his colleagues in Medicine, as exhibited in the subjoined letters must have wearied him greatly. Thus Rush wrote to Coxe on December 8, 1795:

"The lancet has at last become less unpopular in our city. It is introducing Griffiths, Physick, Dewees, Woodhouse and a Dr. Gallagher rapidly into business. . . ."

The lancet refers, of course, to blood-letting —bleeding—a favorite procedure with Rush; and on April 28, 1796, the latter, again addressing Coxe, said:

"Dr. Barton has succeeded Griffiths as Professor of Materia Medica in our University. Dr. James Woodhouse was opposed to him. He lost the appointment by three votes. Dr. Shippen was Barton's *open* friend, and the other professors (Woodhouse and myself excepted) did not oppose him—hence his success! I consider him as a recruit to the enemies of the new System of Medicine and that he will be supported in proportion as he barks at me."

The Barton thus alluded to was the eminent botanist, Benjamin Smith Barton, who received his medical degree from the University of Goettingen in the year 1789. It was in the field of Materia Medica that he won for himself the high professional reputation he enjoyed

in medicine. He was termed the Father of American Materia Medica, an honor which no one hesitated to accord him.

Woodhouse's opposition to Barton very probably sprang from a desire to please Rush to whom he felt deeply obligated.

This incident was, so far as can be ascertained, the last of those internal disturbances in which Woodhouse participated. They were far from his ordinary attitude and likes. The irony of fate often is very striking. It was so in the instance of Barton and Rush, for upon the demise of the latter, the former was chosen as his successor in the chair of the Practice of Physic.

The constant activity of Woodhouse in chemical pursuits, the knowledge that it was possible, under his direction, to conduct actual laboratory work had their effect. Not only students of medicine, but also students who preferred chemistry, seeking advancement in it alone, gradually caused a goodly company of eager, capable young men to gather around him in search of new light in their favorite subject. Among these was Robert Hare, destined in later years, to become a commanding figure in chemical and physical science, of whose early success Woodhouse was enthusiastically proud and of whom he once said, "that he was much

gratified in witnessing the taste for Chemistry had rapidly increased not only among students of Medicine, but also among Gentlemen engaged in other pursuits"—and added that he knew "few if any who had acquired a more accurate knowledge of Chemistry than Robert Hare."

And in time, came Benjamin Silliman, from New Haven. From his diary are culled these interesting items. They will aid us in visualizing Woodhouse's work shop and the happenings in those days:

"The lectures of Dr. James Woodhouse . . . were given in a small building in South Fifth Street, opposite to the State-House yard. Above, over the laboratory, was the Anatomical Hall. Neither of these establishments was equal to the dignity and importance of the School, and the accommodations in both were limited; the lecture rooms were not capacious enough for more than one hundred or one hundred and twenty pupils, and there was a great deficiency of extra room for the work, which was limited to a few closets. The chemical lectures were important to me, who had as yet seen few chemical experiments. Those performed by Dr. Woodhouse were valuable, because every fact, with its proof, was an acquisition to me. The apparatus was humble, but it answered to exhibit some

of the most important facts in the science; and our instructor delighted in the performance of experiments. He had no proper assistant, and the work was imperfectly done; but still it was a treasure to me. Our Professor had not the gift of a lucid mind, nor of high reasoning powers, nor of a fluent diction; still, we could understand him, and I soon began to interpret phenomena for myself and to anticipate the explanations. Dr. Woodhouse was wanting in personal dignity, and was, out of lecture hours, sometimes jocose with the students. He appeared, when lecturing, as if not quite at his ease, as if a little fearful that he was not highly appreciated,—as indeed he was not very highly.

"In his person he was short, with a florid face. He was always dressed with care; generally he wore a blue broadcloth coat with metal buttons; his hair was powdered, and his appearance was gentlemanly. His lectures were quite free from any moral bearing, nor as far as I can remember, did he ever make use of any of the facts revealed by chemistry, to illustrate the character of the Creator as seen in His works. At the commencement of the course he treated with levity and ridicule the idea that the visitations of the yellow fever (1793) might be visitations of God for

the sins of the people. He imputed them to material agencies and physical causes—forgetting that physical causes may be the moral agents of the Almighty. His treatment of myself was courteous. I dined with him in his snug little bachelor's establishment,—for he had no family, and a matron housekeeper superintended his small establishment. I should add respecting his lectures that they were brief. He generally occupied a fourth or a third of the hour in recapitulating the subject of the preceding lecture, and thus he advanced at the rate of about forty or forty-five minutes in a day."

It is not easy to reconcile the statement of Silliman relative to the non-appreciation of Woodhouse with others previously cited, for almost all other estimates of him are very complimentary. Silliman had come out of cold, stern New England, and finding many things in the early capital of our country so vastly different from those to which he was accustomed, may have permitted his criticism to extend even to his teacher, for elsewhere he wrote:

"I had not reason to regret that I attended on the lectures of Dr. Woodhouse. He supplied the first stepping stones by which I was enabled at no distant day to mount higher."

Caldwell, whose picture of Woodhouse is drawn on another page (66), is the authority for the following statement:

"Dr. Woodhouse's didactic lectures rarely occupied, each of them, more than forty minutes . . . and often not near so much. And when interrogated on the subject, the reason he rendered for such brevity was that 'no man could dwell, in discussion, on a single topic more than five minutes without talking nonsense.'"

Caldwell speaks in his hypercritical way of Woodhouse's delivery "as dull and monotonous."

Having heard that students came to Woodhouse's laboratory to engage in laboratory instruction prompts the query as to whether a bit of injustice has not been committed by these two students—Silliman and Caldwell. Laboratory work is claimed as one of the great virtues of the later chemical teaching. It is a distinguishing feature of modern scientific training; yet Woodhouse resorted to this method. It proved, in his hands, to be a powerful attraction, and this fact should be remembered. It is one of the directions in which he figured in the rôle of pioneer. It is to be presumed that there were few if any other laboratories of the Woodhouse type. It explains the presence of Silliman in Philadelphia in 1802–1803–1804.

Further, the value of direct experimentation surely explains Woodhouse's reason for publishing in 1797, "*The Young Chemist's Pocket Companion;* connected with a Portable Laboratory." This, as elsewhere remarked,* was "in all probability, the first published guide in experimentation for chemical students." It afforded the means of carrying forward his laboratory students with more ease. Anyone working privately could easily pursue a most valuable course with the aid of this guide. It deserves and will repay an examination by present day students of chemistry. Teachers cannot fail to be interested. It shows how from the humblest efforts mighty results accrue. It is an inspiration. It was a small volume, covering just fifty-six octavo pages. How it was received in 1797 is evident from the review which was published in the first volume of the *Medical Repository* for that year:

"The performance before us affords a new proof of the prevalence of a taste for chemical researches in the United States. And it is one of the circumstances of recommendation to the *Young Chemist's Pocket Companion,* that it is intended to advance the knowledge of that science, by facilitating the means of making experiments, and of interpreting and

* Chemistry in America, p. 76, D. Appleton & Co.

understanding them. So laudable are all attempts of this kind, that we cannot forbear thinking the author has done service to his favourite branch of philosophy, by the present publication, which may induce many persons to make themselves acquainted with the chemical action of bodies, and thus become able experimenters. Elementary and practical essays of this kind, are highly useful for initiating beginners, and we are pleased to find Professor Woodhouse condescend to collect and arrange a series of experiments, calculated to allure the mind along from object to object, and beguile it, as it were, into an acquaintance with the principles of some of the most interesting phenomena of Nature.

"The author has prefixed to this work, a catalogue of the substances and apparatus for making experiments, contained in the portable chest, connected with it. And the number and variety of these are such as to permit a great number of experiments to be made. A collection of so many chemical preparations, in so compact and handy an arrangement, may be exceedingly useful to almost every person who is fond of these kinds of researches.

"The number of detailed experiments which Professor Woodhouse has given, is one hundred; in which he explains the properties of air or

gases, of alkalies, of acids, of earths and metals. The explanations are concise and generally correct. At the end of the experiments, is an advertisement of the Professor's lectures, given annually in the University of Pennsylvania.

"As the work is intended for those who wish to become practically acquainted with the science of chemistry, we recommend it, and the Portable Laboratory, to the students and cultivators of experimental physics; not doubting that the younger class of inquirers will be considerably aided by it, especially if they peruseit, in connection with such systematical works as those of Lavoisier, Fourcroy and Chaptal."

As a matter of interest the following abstracts from this historical brochure are here introduced:

"Of Iron," Woodhouse writes:

"Iron is a metal of a white livid color; obedient to the magnet; gives fire with the flint; is susceptible of a fine polish, and is very difficult of fusion.

"Experiment LXVI

"Drop some iron filings through the flame of a candle, and the metal will inflame.

"The sulphuric acid will not act upon iron, unless it is diluted with water.

"Experiment LXVII

"Put some iron filings in a vial, and pour upon them a small quantity of the sulphuric acid, and no action will ensue.

"Experiment LXVIII

"Add a quantity of water, equal to four or five times the bulk of the sulphuric acid, to the sulphuric acid and iron filings, and a high degree of heat will be evolved, and a discharge of foetid hydrogenous gas will take place, as may be proved by applying a lighted taper to the mouth of the vial.

"The salt formed by the union of the acid and metal, is sulphate of iron, green vitriol or copperas.

"Experiment LXIX

"Let fall a few drops of this solution of iron into some water in a wine glass, and add a small quantity of the solution of potash to it, and the iron will be precipitated.

"Experiment LXX

"Add a few drops of the sulphuric acid to the precipitated iron, and sulphate of iron will be recomposed.

"Black ink is made by an union of the gallic acid and iron, which form a black insoluble

salt, that is kept suspended in water, by the addition of a gummy matter.

"EXPERIMENT LXXI

"Let fall a few drops of the solution of sulphate of iron, into a wine glass containing some water, to which add a few drops of the alcohol of galls, and a black color will be produced.

"The gallic acid of the alkohol of galls, unites to the iron, and forms a black insoluble salt.

"EXPERIMENT LXXII

"Add a few drops of the sulphuric, nitric, or muriatic acid, to the precipitated iron, and it will be redissolved, and a sulphate, nitrate, or muriate of iron will be formed.

"EXPERIMENT LXXIII

"Pour a small quantity of the solution of sulphate of iron, into a wine glass containing water, and add to it a few drops of the sulphuric, nitric, or muriatic acid, and no change will take place. Let fall a few drops of the alcohol of galls into the solution, and there will still be no alteration. Pour in some of the solution of pot-ash, and the mixture will assume a black color.

"The mineral acids prevent the action of the gallic acid on the iron, by having a superior

attraction to the metal. The pot-ash neutralises them, and so permits the gallic acid to unite with the iron.

"Experiment LXXIV

"Write on paper with the solution of the sulphate of iron and dry the letters; and they will be invisible. Dip the end of a feather into the alcohol of galls, and rub it over the letters, and they will become black.

"Experiment LXXV

"Dip the end of a feather into the sulphuric, nitric, or muriatic acid, diluted with water, and rub it over the letters, and they will disappear.

"Prussian blue is a combination of the prussic acid and iron. The prussiate of lime is made, by digesting lime water upon this substance.

"Experiment LXXVI

"Put two drachms of the best Prussian blue, in fine powder, into an eight ounce vial, and fill it up with lime water. Let the mixture stand near the fire, and in a short time the lime water will be tinged yellow.

"Experiment LXXVII

"Let fall a few drops of the solution of sul-

phate of iron into some water in a wine glass, and add to it a small portion of the prussiate of lime, and a blue color will be produced.

"The prussic acid of the prussiate of lime, unites to the iron, and forms a blue insoluble compound, while the sulphuric acid of the sulphate of iron, unites to the lime and forms sulphate of lime.

"Prussiate of pot-ash, is composed of the prussic acid and pot-ash.

"Experiment LXXVIII

"Put two drachms of the best Prussian blue into a four ounce vial, and add to it one drachm of caustic pot-ash, dissolved in three ounces of water; set the mixture near the fire, and in a short time the liquor will become a yellow color.

"The pot-ash unites to the prussic acid, of the prussiate of iron, and forms prussiate of pot-ash, while the iron is left behind in the form of a brown salt.

"This solution contains a portion of iron, which may be set free, by the addition of an acid.

"Experiment LXXIX

"Add a few drops of the sulphuric, nitric or muriatic acid, to some of the prussiate of

pot-ash in a wine glass, and the iron will be thrown down of a blue color.

"The acids combine with the pot-ash, by which means the prussic acid is detached from its alkaline base, and permitted to act on the iron, held in solution in the liquor.

"Experiment LXXX

"Write upon paper, with the solution of the sulphate of iron, as in the seventy fourth experiment.

"Experiment LXXXI

"Dip the end of a feather in the prussiate of pot-ash, and rub it over the letters written with the sulphate of iron, and they will become of a blue color."

The laboratory of the Chemical Society of Philadelphia had invited citizens of the Republic to forward to it any "fossils" upon which they wished information and as President Woodhouse was active in the work of the laboratory there fell to his lot a rock from North Carolina, submitted by Rev. James Hall. This was in the year 1798. Woodhouse's examination and reply to Hall were published in the *Medical Repository*. They are so intensely interesting, particularly to the master of chemical analysis,

that the communication is submitted in unabridged form:

"SIR,

"I have read your account of a supposed artificial wall, discovered under the surface of the earth, in North Carolina, with great attention.

"I am well satisfied, from several specimens of the stones which I have seen composing this wall, that it consists of a mineral substance called basaltes, and that it is a production of nature, and not of art.

"My reasons for this opinion are as follows:

"The stones answer the description of basaltes given by various writers. They are found of an irregular form, in prisms consisting of several sides, are of different sizes; some being so small as to weigh no more than one ounce, while the others exceed the weight of twelve pounds. The angles fit each other exactly like the basaltes, and appear as if joined by the hand of a skilful workman.

"There is a brown ochreous matter found upon the surface of these stones, exactly like that on some of the basaltes of other countries. This ochre arises from a chemical decomposition of the stone, called by some spontaneous calcination, and by others efflorescence.

"The decomposition is owing to the iron contained in the stones, and its calcination by air and water.

"Fourcroy has improperly attributed the brown crust with which the stones are covered, to water depositing different kinds of earth between the sides of the basaltic columns; and in Nicholson's Chemical Dictionary it is called cement with equal impropriety. Columns of the Giant's Causeway, says the compiler of the Dictionary, fit accurately together, being, in some instances, united by a strong cement.

"That the brown crust which adheres to the stones, and the fine white friable matter with which you suppose the wall has been plastered, are owing to chemical decomposition, appears evident from the following circumstances: If the brown ochre is carefully scraped off from the stone, the surface will be found to be not of so firm a texture as the internal part; and the white powder, brown crust, and internal part of the stone, are composed of the same principle, in nearly the same proportions.

"In some countries the basaltes are so much calcined as to fall to pieces on being removed.

"The regularity of the wall, and the number of small stones which appear as if slipped in between the ends of the stones, are no proofs

of its being a production of art. The basaltes, in Italy, appear like piles of wood of equal thickness throughout, and extend to a considerable distance. The small stones may have been carried down from the surface of the earth by rain, and deposited in the places where they are now found.

"I do not suppose that the rock which embraces the wall, and which, from the specimen you have shewn me, is granite, was formed after the wall, granite being among the first formed substances in nature. The rock has probably been burst asunder by the wall, which is, perhaps, of volcanic origin.

"In Cronstedt's Mineralogy there is an account, by Mr. Latrobe, of a rock of granite in Upper Lusatia, which has been rent asunder by a vein of concentric basaltes. In Italy basaltes are often found resting upon a bed of granite.

"That there have been volcanoes in North Carolina appears from some specimens of lava sent from that part to this city.

"The following experiments were made in order to ascertain the component parts of the American basaltes:

"EXPERIMENT I

"One hundred grains of the solid stones

were reduced into an impalpable powder, and boiled half an hour in half an ounce of nitric acid, diluted with one ounce of water. The whole was placed upon a filter, and distilled water was added until it passed through the filter—insipid to the taste. The powder remaining upon the filter was siliceous earth, and when dry, weighed exactly fifty-eight grains.

"Experiment II

"A solution of potash was added to the fluid which passed through the filter until no precipitation took place. The precipitated matter was carefully washed in a large quantity of distilled water, and, when dried, weighed forty grains.

"Experiment IV

"That part of the dried precipitate, mentioned in the second experiment, which was not acted upon by the vinegar, weighed twenty-nine grains. It was dissolved in diluted nitric acid, and a solution of the prussiate of potash was added until no precipitation took place. The prussiate of iron was separated by a filter, boiled in a solution of pot-ash, washed well with distilled water, and dried, when it weighed ten grains.

"EXPERIMENT V

"A solution of pot-ash was added to the filtered liquor of the last experiment, until no precipitation took place. The precipitate, which was alumine, was well washed in distilled water, and when dry, weighed sixteen grains.

"The proportions of the ingredients composing the American basaltes, from these experiments, are fifty-eight parts of siliceous earth, sixteen of argillaceous, three of magnesia, and ten of iron, which added together, make eighty-seven. Counting two grains lost in the first experiment, and five in the other, we will have ninety-four grains, which, with six allowed for the lime, will make one hundred grains.

"One hundred grains of the white friable matter called cement, and the same quantity of the ochreous crust, when subjected to the same kind of experiments, gave the following result:

	Silex	Alumine	Lime	Mag.	Iron	Loss
White friable powder...	55	16	5	3	12	9
Brown ochreous crust...	54	15	6	3	11	11
Powdered stone........	58	16	6	3	10	7

"Upon comparing this analysis with those of Bergman, Mongez, and Faujas de Saint Fond, no great difference will be found in the proportion of the ingredients composing the American basaltes and those of other countries.

"Analysis by Bergman, Mongez, Faujas de Saint Fond:

Silex	52	56	46
Argillaceous earth	15	15	30
Lime	8	4	10
Iron	25	25	8
			6 Magnesia
	100	100	100

"This wall is certainly a great curiosity, and will afford ample room for the speculation of philosophers.

"I should be happy to receive any further information upon the subject.

"I am, Sir, with the greatest respect,

"Your most obedient and humble servant,

"JAMES WOODHOUSE

"Rev. James Hall,

June, 1798"

Chemists who have had occasion to study Klaproth's *Beiträge zur chemischen Kenntniss der Mineralkörper* will not regard the observations of Woodhouse as unworthy of attention. They reveal the crude state of analysis existing then; but despite this they are worth recording. Any student of present day analysis will see merit in this early work.

The report of Woodhouse called forth objec-

tions from the Rev. Zechariah Lewis. In reply, Woodhouse addressed him, through the editors of the *Medical Repository*, in these words:

"GENTLEMEN,

"If Mr. Zechariah Lewis had seen my reply to the Rev. Mr. Hall's account of the celebrated subterranean wall of North Carolina, published in the *Medical Repository*, vol. ii, p. 275, he could not have asserted, that the opinion that the wall was basaltic was hastily adopted, from a single corresponding property having been discovered between the stones composing the wall and basaltes. When he reads that reply, he will find various reasons brought forward in support of the opinion there advanced; several authors who have written on the subject in question quoted; an accurate analysis made of the external and internal part of the stones, and of what is improperly called the cement, and compared with the results of the experiments of Bergman, Mongez, and Faujas de Saint Fond, on the basaltes of other countries.

"Having made these necessary observations, I will proceed to consider the arguments produced by Mr. Lewis, to prove, that the wall is a production of art.

"First. It may be remarked, that the opinion that the wall was constructed by some en-

lightened antediluvian nation, or some civilized people, who may have wandered from the eastern continent; or that it was built for the purpose of inclosing a prison, a garden, or a city; or that the small stream which runs near the wall was once a large river, and that the wall was erected to guard against the rise of its waters, has no foundation but in the imagination of the reverend writer.

"Secondly. He thinks that the fine white powder, called cement, with which the wall is supposed to have been plastered, may have been manufactured from the shells of muscles, great quantities of which are found in the neighborhood of the wall. Mr. Probly, he says, assured him, that he burnt the shells, dried the cement, and upon comparing the two, could find no difference between them.

"Muscle shells, exposed to the action of fire, are almost entirely converted into quick lime; but in one hundred parts of this cement, there is no more than five parts of this earth. Muscle shells contain no iron, but there is a considerable portion of the metal in the cement.

"One hundred grains of these shells will not afford, like the cement, fifty-five grains of silex, sixteen of alumine, and three of magnesia. Mr. Probly has not favoured us with any chemical experiments, to prove that there is no

difference between burnt muscle shells and the cement; the only proper method of proving a similarity between these bodies.

"Thirdly. At a small distance from the wall, Mr. Lewis informs us, there is a species of clay resembling fuller's earth of which the cement may likewise have been made. What is called fuller's earth, never turns of a white colour like the cement; and the clays of this country, with few exceptions, burn of a red colour. The cement retains its whiteness, when exposed to a heat insufficient to melt it. In order to prove that the cement is composed of fuller's earth, or this kind of earth mixed with burnt muscle shells, it will be necessary to show that a mechanical mixture of these substance gives the same principles by analysis as the cement.

"Fourthly. He says the wall is perfectly regular, and has every possible appearance of an artificial production.

"In my letter to Mr. Hall it was expressly mentioned, that the regularity of the wall was no proof of its being a production of art; for the basaltes of Italy appear like piles of wood, of equal thickness throughout, and extend to a considerable distance.

"The following account of the cave of Fingal, extracted from Garnet's tour through Scotland,

will show how little regularity of the wall contributes to prove that it has been the production of a civilized people.

" 'As we turned the southern point of the island of Staffa, the basaltic pillars became vastly more regular, and the view of this side of the island was grand beyond conception: it appeared like the end of an immense cathedral, whose massy roof was supported by stupendous pillars, formed with all the regularity of art. Proceeding still further along the same side of the island, we had a view of Fingal's cave, one of the most magnificent sights the eye ever beheld. It appears like the inside of a cathedral, of immense size, but superior to any work of art, in grandeur and sublimity, and equal to any in regularity.

" 'Regularity is the only part in which art pretends to excel nature; but here nature has shewn, that when she pleases she can set man at nought, even in this respect, and make him sensible of his own littleness. Her works are, in general, distinguished by a grand sublimity, in which she disdains the similar position of parts, called by mankind, regularity, but which, in fact, may be another name for narrowness of conception, and poverty of idea; but here in a playful mood, on a scale so immense, as to make all the temples built

by the hand of man hide their diminished heads.' "

"Dr. Van Triol, speaking on the same subject, says—'This piece of nature's architecture far surpassed every thing that invention, luxury, or taste, ever produced among the Greeks.'

"Fifthly. An extract is made from the British Encyclopædia, to show that basaltes is always found standing up in the form of regular angular columns.

"This is not true. The strata of the basaltes of some parts of France run in an horizontal direction.* Mr. Strange in an essay published in the sixty-fifth volume of the London Philosophical Transactions, asserts, that they sometimes are found running in this manner.

"Sixthly. He says there is nothing between the basaltic columns of other countries, resembling the cement of the wall.

"This observation is not just. A cement of a beautiful white colour is found between the basaltic pillars, in the cave of Fingal.†

"Seventhly. It is another property of basaltes, adds he, that it is fusible, per se, by a moderate fire. This is not the fact with the wall, consequently it cannot be basaltes.

"To this I reply, that I have fused the stones

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* Historie Naturelle de la France Meridionale, par M. L'Abbe Giraud Soulavie, tom. ii, p. 52.

† Gamet's Tour through the Highlands, p. 224.

of the wall, in half an hour, with the greatest ease, and that they melt into a black glass.

"Eighthly. Neither stones, nor other mineral substances, our author informs us, are covered with rust, unless they have been exposed to the action of the aerial acid. On the supposition that the wall is basaltes, the individual stones could never have been exposed to the air. The stones are covered with rust, consequently the wall cannot be basaltes.

"The first part of this observation is not accurate. Mr. Lewis has not proved, that the rust of the stones contains the aerial acid, which he ought not to have taken for granted. The word rust is a vague term, and conveys no precise idea to the mind. The brown ochreous matter, with which the stones are covered, has been formed by the agency of water, acting upon the iron they contain, which has decomposed or calcined them. The aerial acid has no action in the business. The same kind of rust is found on the basaltes of other countries.*

"Ninthly. The stones composing the wall are certainly basaltic, as every mineralogist can tell by inspecting them, because they exactly answer the description of basaltes given

*French Encyclopædia, and Nicholson's Chemical Dictionary—article Basaltes. Vide also Fourcroy's Chemistry.

by various writers; and because the white powder, improperly called cement, the external and internal parts of the stones, contain the same principles, and nearly in the same proportions as the basaltes of other countries.

"I shall conclude this letter, by remarking, that the supposition that the North Carolina wall has been constructed by an enlightened antediluvian nation, is as unphilosophical as the belief of some of the common people of Scotland, that the cave of Fingal is artificial, and was built by a race of giants, for their celebrated chief, Fion-Mac-Cool, the father of Ossian.

"I have the honour to be,

"Gentlemen,

"Yours sincerely,

"James Woodhouse."

Some years afterwards (1803), Woodhouse felt called upon to advert again to the comments of the Rev. Lewis. This was done through the *Medical Repository*.

"Gentlemen:

"Since my return from Europe to America, I have not met with anything which has afforded me more entertainment than the reply of the Rev. Mr. Lewis to my letter concerning the subterranean wall of North Carolina. When

this subject was brought before the public, in the year 1798, two questions were involved:

"First. Whether the stones composing the wall were basaltic: and,

"Secondly. Whether the wall was a production of nature or of art.

"In a postscript to a letter of Mr. Lewis's published in the fourth volume of the *Medical Repository*, p. 233, he pronounces in the most positive manner, that the stones composing it are not basaltic. He concludes his remarks, in four places, in the following words: 'consequently the wall cannot be basaltes.' But in his reply to my observations, in the fifth volume, p. 404, he says, 'the question in dispute is not, whether the materials are basaltic, but whether the wall is a work of art or of nature.'

"It is not my intention to bring forward any arguments, in addition to those already published, to prove that this wall is basaltic. A mineralogist can distinguish basaltes from any other stone merely by inspecting them, as well as any other person can tell an apple from an orange, a pear from a peach, or any one of the common productions of nature from another.

"The chemical analysis, likewise, of the solid stones, and what is improperly called rust and cement, demonstrates in a satisfactory

manner, to chemists, that the stones are basaltic and there can be no appeal from the experiments, except by showing that they have been made in an improper manner.

"Mr. Lewis asserted, on authority which he says is too direct and respectable to admit, for a moment, a doubt of its correctness, that I reported, after his reading my reply to his letter, that he was convinced of his error, and had published a retraction of his sentiments. No such report ever was propagated by me. When in New York, in the year 1801, I was informed that he did not relish my reply; and I might have said that he would regret having written any thing upon the subject of the wall; for so powerful is self-love, that few men are pleased with being caught in an error, or with having their opinions publicly called in question, much less with having them refuted.

"Thus, in the year 1712, Dr. Cotton Mather, having inspected some large fossil bones and teeth, found at Albany, in New York, wrote to his friend, Dr. John Woodward, in England, that they belonged to American giants, whom he supposed to have existed before the deluge, and of whose height he made a calculation.*

* Philosophical Transactions for 1713 and 1714, Vol. XXVIII or the Abridgment, Vol. V, Part 2.

"Were this gentleman now alive, and were he to behold the skeleton of the mammoth in Mr. Peale's museum in this city, he would be convinced that they were really the bones and teeth of a similar huge quadruped; and he might feel a little mortified that he had ever written to Europe that they belonged to the Brobdignagian biped of the antediluvian world.

"An accurate account of this celebrated wall will form an important article in the mineralogical history of this country; and Mr. Lewis will oblige the friends of science by devoting a part of his time to a further investigation of this curious subject.

"As he has found out that the stones composing it are not basaltic, that the decomposed granite, which embraces it, and of which specimens were brought to Philadelphia by the Rev. Mr. Hall, and one of which is now before me, is nothing but 'sand and gravel'; he will, perhaps, next discover that the supposed cement with which the sides of it are covered is the plaster of Paris.

"If he does, I will believe with him that the wall was built by antediluvians, to enclose a garden, a prison, or a city, or for any other purpose which he pleases.

"I thus, gentlemen, take leave of the wall,

and of the Rev. Mr. Lewis; and am with great respect,

"Yours sincerely,

"James Woodhouse"

That the problems considered by Woodhouse varied in their nature is shown, for example, in a contribution made by him (1799) on the non-action of nitric acid on the metals, silver, copper, and tin. Having occasion to prepare silver nitrate "several thin pieces of silver were digested forty-eight hours, in a small quantity of the most pure and concentrated acid, prepared by distilling strong sulphuric acid in nitre, from which the water of crystallization had been thrown off by means of heat, and the metal was not dissolved. The temperature of the air varied between 75 and 90 degrees of Fahrenheit's thermometer."

This behavior greatly surprised Woodhouse. It was quite contrary to his expectations. "According to the chemists of all nations" the nitric acid should have dissolved the silver "with the utmost rapidity." It occurred to him that the non-action of the acid might be due to the fact that the metal was "in small masses." Accordingly the "filings of silver were tried, but no solution took place in the space of two days." His mind was set some-

what at rest in a very simple manner: "having then added a small quantity of water to the acid, the silver was dissolved in a few minutes."

This, now familiar, behavior of metals with this particular acid is here set forth for the first time, but cautiously Woodhouse proceeds to ascertain whether the same deportment would be observed with other metals; and selecting copper continues; "nitric acid was poured upon copper and no action was produced; but, upon the addition of water, solution immediately commenced, and oxygenous and nitrous air were discharged; the latter holding a portion of the copper in solution, as appeared by immersing a lighted taper in the nitrous acid gas, when it burned with an enlarged, vivid and blue flame. The flame of the taper was frequently blown out, and rekindled by dipping it into the air."

Not fully satisfied, he drew tin into the circle of experimentation and investigation, after which he was constrained to write: "some concentrated nitric acid was then poured upon tin foil, when it remained in a quiescent state *for one week;* but upon the addition of water, the whole was instantly converted into a white oxyd, with the production of a high degree of heat."

There is every reason to suppose that Wood-

house was more or less perturbed by these observations; yet he knew no reason to question their correctness, and boldly declared:

"The errors of chemists, in regard to the action of nitric acid upon tin, will be seen more clearly by extracting what has been said upon the subject.

"Chaptal tells us the nitric acid devours tin, that the decomposition is speedy, and that the metal is instantly precipitated in the form of a white oxyd. The same author says, Mr. Baumé even pretends that the nitric does not dissolve tin; but Kunckel and the famous Rouelle have maintained the contrary.

"Fourcroy declares that tin decomposes nitric acid, even in the cold, with amazing rapidity, and that this is one of the most astonishingly rapid solutions in all chemistry.

"From what has been said, it appears that Mr. Baumé is right, and that Fourcroy, Chaptal, Rouelle, and Kunckel, used an acid diluted with water."

Aware that his observations would arouse inquiry as to the course of the reaction he immediately put to himself this query: "In what manner does water act in these experiments?"

"Dr. Priestley supposes that no air can be produced without water, and that it is neces-

sary to the constitution of every kind of air; but this throws little light upon the subject, and does not account for the manner in which water acts in promoting the solution of silver, copper, and tin, in the nitric acid; and nitrous air may be obtained from zinc and bismuth by the acid, however concentrated.

"It may be supposed, that the water merely produces heat by uniting with the acid, and so dissolves the metals; but this is not the case; for if the acid is diluted with water, and stands until it is cool, it will speedily dissolve them.

"It is a common thing with the teachers of chemistry to fold up a portion of the dry nitrate of copper in the tinfoil, and to let it remain, for some time, in contact with the tin, to show that it will not act upon the metal in the dry state. The tinfoil is then unfolded, and a little water is added to the nitrate of copper, and it is again enclosed in the tin, when a violent action ensues, accompanied with sparks of fire, and a discharge of nitrous air.

"The intention of this experiment is to show that bodies do not act upon each other in a dry state—corpora non agunt nisi soluta. But from the experiments which have been related, of the non-action of the nitric acid on tin, the explanation of what takes place must be

sought for in the action of water on the nitric acid of the nitrate of copper.

"Some writers have taken notice of the production of ammoniac, when nitrous acid is added to copper and tin. As the concentrated acid has no action on these metals, the ammoniac must be produced by the hydrogen of the water uniting with the azote of the nitric acid, while its oxygen, and that of the water, unites to the tin and copper, and converts them into oxyds.

"Having related these facts, the language of chemists, in the future, ought to be—The nitric acid has no action on silver, copper, and tin; but if water be added to the acid, solution speedily takes place.

"Dr. Hope has taken notice of the non-action of the nitric acid on strontian earth; and Mr. Leonhardi tells us, that it quickly destroys wool and silk, but that linen may remain immersed in a bottle of the strong acid a whole day without injury."

Today, the youngest chemist would promptly explain these reactions. The science was long in comprehending them and present-day dissociation theories would have staggered Woodhouse. His communication might be called worthless by some. Would they not err in so designating it? Is it not rather to be prized

because it is a sign board indicating the road or path by which chemists have arrived at their present views?

Some years later (1801) there appeared (*Medical Repository*, Vol. III, p. 415) what purported to be a denial of Woodhouse's views. It read:

"The more nearly the nitric acid approaches to purity, the more powerfully Mr. Carrendeffez finds it acted upon by silver, copper and tin, notwithstanding its strength and concentration, provided its water of liquidity be not too much diminished."

To this Woodhouse immediately answered:

"I have since frequently repeated these experiments, and still adhere to my former opinion, which I consider as just.

"If nitric acid, prepared from the common oil of vitriol and nitre of the shops, can be kept, for weeks or months, over silver, copper and tin, without affecting those metals, and if they are acted upon in a most violent manner instantly when water is added to it, certainly we ought to conclude that the acid will not affect them, and that water is necessary to its action.

"The phenomena which accompany the solution of each of these metals, in the acid, are considerably different.

"When the diluted acid is added to tin, a most violent commotion ensues, accompanied with a discharge of common nitrous and dephlogisticated nitrous air, and the formation of the nitrates of tin and ammoniac, and a large quantity of the white oxyd of tin.

"This experiment affords us a strong andelegant proof in favour of the *decomposition of water, the corner stone of the new theory of chemistry.*

"The hydrogen of the water unites to part of the azote of a portion of the nitric acid, and generates ammoniac, which joins to some of the nitric acid, and makes nitrate of ammoniac. A second part of the azote of the acid lays hold of part of the oxygen of the acid and water, and produces common nitrous air. The remainder of the azote seizes upon another portion of the oxygen of the water and acid, which gives rise to the dephlogisticated nitrous air. A third part of the oxygen of the acid and water joins to the tin, converts it into a white calx, which makes the nitrate of tin.

"If water is so essential to the action of the nitric acid on tin, in what manner is the ammoniac produced, or from whence comes the hydrogen which enters into the composition of this substance? It is necessary to add lime, pot-ash or soda to the solution of tin in nitric acid, to disengage the alkaline gas."

Silliman, the elder, states in his *Elements of Chemistry*, p. 233, relative to tin and nitric acid: "When cold there is no action; a strip of tin foil may be kept in a bottle of the acid for years, without being corroded, provided the air be excluded," and in a footnote adds, "this was first mentioned by the late Dr. James Woodhouse of Philadelphia, at the time when I was his pupil in 1802–3 and 4."

Silliman records that he kept tin-foil in a bottle of the strongest nitrous acid for years, without any action, the tin remaining bright."

When Woodhouse distilled a quantity of the bones of horses and cows in a distilling apparatus, formed of iron, which communicated with the worm of a refrigeratory, to which a large glass receiver was annexed, on applying a high degree of heat, "three ounces of volatile alkaline spirit, impregnated with the black animal oil of Dippel, were obtained in three hours. The receiver was closely luted to the worm, and the air in it was perfectly transparent. Upon taking away a part of the lute, in such a manner as to permit the air of the atmosphere to enter the receiver, it became immediately filled with a thick brown yellow cloud of smoke.

"Having made a variety of comparative

experiments, to determine the difference in the quantity of the product, by distilling with and without the lute, it was found that five times as much of the volatile alkaline spirit could be obtained by carrying on the distillation without the lute, as could be procured, in the same space of time, with the application of the lute.

"Lavoisier supposes, that when ammoniac is obtained from animal substances, the hydrogen and the azote of these bodies unite together, and form the volatile alkali; but it appears from what has been said, that the azotic air of the atmosphere enters into the worm of the refrigeratory, joins the hydrogen of the bones, and so forms the ammoniac.

"Manufacturers of the volatile spirit of sal ammoniac may take some valuable hints from these experiments."

Practical problems of this sort were certain to arrest his attention. He had the interests of the public in mind, for he wrote, when "a quart of the most putrid urine, and of as yellow a colour as gamboge, was exposed, two nights, to intense cold, it became perfectly sweet, and was as colourless as rock-water." This circumstance occasioned this inquiry:

"May not this wonderful change be attributed to the agency of the oxygen gas of the cold atmospheric air?

"The acid of citrons not only neutralizes the volatile alkali of putrid substances, but completely destroys the nauseous smell which exists, independent of the ammoniac. The sulphuric and muriatic acids have no such effect. Does the oxygen of the citric acid act here likewise? Lowitz, a Russian chemist, supposes that charcoal neutralizes the putrid effluvia of animal bodies; but, in my opinion, it acts mechanically, in preventing the putrid particles of matter from flying into the air."

In discussing the fruit of the Horse Chestnut (Aesculus Pavia), particularly in connection with the starch obtained from it, Woodhouse wrote:

"In the 29th number of the *Repertory of Arts*, there is an account of a patent, obtained by Lord William Murray, for making starch from the fruit of the *aesculus hippocastanum*. A writer in the London *Monthly Magazine* for 1798, says he has repeatedly, and in various ways, endeavoured to make starch of the fruit, but always unsuccessfully; but it turns to a yellow colour."

He continues: "The fruit of our *aesculus pavia* is much larger than that of the *aesculus hippocastanum*, and is of a white colour; that of the hippocastanum is yellow.

"A single nut, dried, weighed half an ounce and twenty-five grains, and yielded forty-four grains of fine starch.

"I prepared half a pound of this starch from the nuts of the *aesculus pavia*, and have kept it two years, and the white colour is in no way impaired. It is superior to the finest Poland starch, and has been used, by several ladies, to starch various articles of dress, without imparting any yellow colour to them.

"The method of preparing it is, to take off the shells from the nuts with a knife; grate them in a vessel of water which will hold the fine particles of the starch suspended, when they are to be decanted into another vessel, which must remain at rest until the starch subsides to the bottom. The water is then to be poured off, and fresh is to be added, and the starch is to be well stirred about in it, when it must again be permitted to subside. The water is then to be thrown away, and the starch is to be dried in the sun.

"The water of the first washing holds a poisonous matter in solution, which, when evaporated to the consistence of an extract,

and mixed with dough, will intoxicate and swell the bellies of small fishes."

The chemistry of plants was a constant source of interest to Woodhouse. He was ready at any moment to institute inquiries regarding them either as a whole, or of particular parts; hence there is nothing strange when he writes of Aromatic Oils, obtained from the Pellicle which envelopes the Seeds of the Laurus Sassafras and Laurus Benzoin, and recommends that "the method of obtaining these oils is to boil the pellicle which surrounds the seeds of the sassafras and Benjamin-tree in water, when they float upon its surface, from which they may be skimmed with a spoon.

"That of the sassafras differs materially from the oil obtained from the bark of the root of this tree. Its aroma is different, it is much lighter, and it congeals in a higher degree of heat.

"The oil of the benzoin-tree is a delightful aromatic, is very inflammable, and might be used as a spice in a food, and in all those diseases in which the aromatic oils are useful. It has been tried with success, as an external application, in a severe case of chronic rheumatism. One half pound of the pellicle of the seeds will yield several ounce measures of oil."

Woodhouse's views of the eudiometer were quite interesting for he wrote: "the eudiometer is an useless instrument in ascertaining the purity of atmospheric air;

"1st. Because nitrous air can never be obtained of the same degree of strength.

"2ndly. When one measure of nitrous air is added to one measure of atmospheric air, the absorption will be great or small, according to the time the air remains over the water, or is agitated in it.

"Having made seven trials with this instrument, with the same atmospheric air, I obtained a diminution, at the first experiment of

	0	60
2nd	0	56
3rd	0	95
4th	0	87
5th	0	90
6th	0	93
7th	0	100

"From this it is evident, that Dr. Davidson was deceived in supposing that the air of Martinique was much purer than the air of Europe, and that the error lay in his instrument. The nitrous air which I used was procured from nitric acid diluted with water and copper."

A discovery, "the best which has been made for many years," is the language in which Woodhouse characterized an observation of Mr. William Lambe "on the Base of the Muriatic Acid." Lambe attempted to prove "that sulphurated hydrogen is the base of muriatic acid." He got oxy-muriatic acid gas by dropping sulphuric acid upon the residuum left after evaporating water which had been impregnated with hepatic gas, in which iron and manganese had been digested." And Woodhouse published that he had "performed this experiment, and the result is exactly as stated by Mr. Lambe."

His procedure was: "Two drachms of the filings of bar-iron were placed in twenty-two ounce measures of distilled water, which had been impregnated with sulphurated hydrogen gas, in Nooth's apparatus. In five days twelve ounce measures of inflammable air escaped from the water. Six ounces of the clear fluid evaporated to dryness, left a residuum, consisting of dephlogisticated muriate of iron, which attracted the moisture of the atmosphere. A few drops of sulphuric acid, let fall upon it, produced an effervescence, and white clouds of oxy-muriatic gas escaped, as was very evident from the smell, and from the tests generally used to detect the presence of this gas."

Here the modern chemist will take issue with Woodhouse; at least, he will be very skeptical, asking what really happened on letting water charged with hydrogen sulphide act upon the filings? If hydrogen escaped, did iron sulphide remain? Could it possibly have been dissolved in the "six ounces of clear fluid," which on evaporation to dryness, gave a residue of muriate of iron? Muriate of iron is iron chloride. Could it be present under the existing conditions just given? It is hardly likely.

Perhaps the original printed document does not contain all that Woodhouse had in mind to say. Again, the distilled water may not have been free of halides. No account is given of the modus operandi in preparing the distilled water. Nor can any one be altogether certain of the "filings." The abstract has little value although there may be those who will regard it as a reflection upon Woodhouse's keenness of observation, or upon his scientific acumen.

Had the reader been permitted to converse with Woodhouse, there seems little doubt but that he would have found him interested not only in all pertaining to chemistry but also in geological subjects, and, as will be observed later, in minerals, in plants, in insects, in short,

in broad, general science topics, so that the following communication relative to "Blistering Flies" peculiar to America, will be considered as legitimate subject-matter even for one holding himself as a chemist in particular.

"I have discovered two other blistering meloes besides that described in the *Medical Repository*. The one I would call *Meloe Clematidis*, as it is particularly fond of several species of this plant. It is larger than the one described by Dr. Chapman, and the female is nearly twice the size of the male. The head, thorax, elytra, and antennæ are black; the elytra only edged with white. The abdomen is of a light ash-colour. The upper part of the abdomen, under the wings, is marked by two longitudinal streaks of a bright clay-colour. The asters are sometimes black with these flise, and the leaves are entirely destroyed by them.

"The other I would call *Meloe Nigra*, the Pennsylvanica of Linnæus. It is not more than half the size of Chapman's fly. The whole of it is black. It feeds upon the prunella vulgaris, or self-heal, and ambrosia trifida, or stick weed.

"I applied a small blister of these flies to my skin, and lost the plaister in half an hour. In twelve hours after a fine blister was produced. A watery extract of the flies blistered

in six hours. Distilled in a retort, they yield an acid, whose properties have not yet been examined.

"Besides these three kinds of meloe, there is another found in this country, mentioned by Kalm, and called by Linnæus meloe majalis; but it is not yet known whether it will blister; for Shoepf expressly asks the question, 'an mel. vesicatorio (cantharid, officinal.) substituendus?'

"We then know for certainty of three kinds of indigenous blistering flies—Meloe Chapmani, Meloe clematidis, and Meloe nigra. Meloe majalis, doubtful."

The closing years of the eighteenth century and the very early years of the nineteenth century were momentous ones in chemical circles in this country; particularly in Philadelphia, where the scientific atmosphere was charged with phlogiston. It could scarcely have been otherwise with Priestley actively advocating the existence of "that principle which is sometimes heavy, sometimes it is not; sometimes it is fire combined with the earthy element; sometimes it passes through the pores of the vessels, and sometimes they are impenetrable to it; it explains at once causticity

and non-causticity, transparence and opacity, colors and the absence of colors. It is a veritable Proteus which changes its form every moment."

It was that strange doctrine—our first chemical theory—which had dominated chemical thought from 1720 to 1789, and while it led to experimentation, placing new facts, as they were obtained, under definite view-points and correlating them, yet it had been found insufficient and had been gradually abandoned by its supporters. Thenard wrote of the Phlogiston Theory:

"Stahl's theory of Combustion, although a great error deserves from its important results to be ranked with the grander discoveries of Chemistry."

And, another writer said, before the Chemical Society of Philadelphia in 1798:

"That theory, which but a few years since commanded the undissenting voice of the chemical world, is now almost wholly forsaken. Still, however, the tottering dome of this once mighty fabric is supported by one solitary pillar, so well constructed as by its single force to uphold it against the warring elements, nor can it ever fall till this pillar is removed. Neither can the doctrine of phlogiston be said to be totally destroyed, until it shall cease to rank among its supporters the name of Priestley."

In other lands the anti-phlogistic views, as enunciated by the great Lavoisier, had gained adherents and may be said to have become established, for even in Germany where national prejudice declared in favor of phlogiston, the renowned Klaproth, having performed the experiments of Lavoisier before the Academy of Berlin, and convinced of their truth, adopted in 1792, in conjunction with other eminent scientists of his country, the teachings of the French School.

As accurately as could be ascertained a question so burning as that of the existence or non-existence of phlogiston commanded very earnest thought in this new land, and there appears to have been a leaning toward the newer views, but the advent of Priestley developed fresh interest in the problem. His stormy life in the last years of his residence in England gave him little opportunity to conduct his scientific inquiries, but "being settled at Northumberland with his mind at peace, and at ease in his circumstances, he seriously applied himself to those studies which he had long been compelled to desist from. . . . His studies were very varied."

About the year 1799, the friends of liberty in America were greatly alarmed by the advancement of principles disgraceful to America;

and by a practice less liberal in many respects than under the monarchical form of the British Government.

Priestley's son wrote: "Nothing else was the subject of conversation, and my father though never active in politics, at the same time never concealed his sentiments. . . . The consequence was that all the bigotry and party zeal of that violent period was employed to injure him, and misrepresent his words and actions. . . . It was intimated to my father, from Mr. Adams himself, that he wished he would abstain from saying anything on politics, lest he should get into difficulty. . . ."

And in *Political Tracts* many disagreeable things were said of him by Peter Porcupine.* For example:

"Of all the English arrived in these States (since the War) no one was ever calculated to render them less service than Dr. Priestley; and what is more, perhaps no one (before or since, or even in the War) ever intended to render them less: his preference to the American Government is all affectation: his emigration was not voluntary: he staid in England until he saw no hopes of recovering a lost reputation; and then bursting with envy and resentment,

* The pen name of William Cobbett, an interesting character. A confirmed pamphleteer.

he fled into what the Tammany Society, very justly call 'banishment,' covered with the universal detestation of his countrymen. . . . He is a bird of passage that has visited us, only to avoid the rigour of an inclement season: when the reanimating sunshine of revolution shall burst forth on his native clime, we may see him prune his wings, and take his flight from the dreary banks of the Susquehannah to those of the Thames or the Avon."

This gives a picture of some of the experiences of Priestley, but in the midst of them all he experimented and published his treatise in defense of Phlogiston (1800). And his son said: "But the last four years of his life he lived under an administration, the principles and practices of which he perfectly approved, and with Mr. Jefferson, the head of that administration, he frequently corresponded, and they had for each other a mutual regard and esteem. He enjoyed the esteem of the wisest and best men in the country, particularly at Philadelphia, where his religion and politics did not prevent his being kindly and cheerfully received by great numbers of opposite opinions in both, who thus paid homage to his knowledge and virtue."

American chemists, of all ages, will find ample justification for congratulation that their fore-

fathers, not only in Philadelphia, but throughout the cities of the young Republic, were among those who kindly received and "paid homage" to the sturdy defender of a lost cause—the sage and philosopher—who gave so much of himself to conferring happiness upon his fellow-men.

Among his closest friends in chemical circles were McNevin of New York (1764–1841), author of a neat, favorably received volume entitled "An Exposition of the Atomic Theory," Mitchill (1764–1831) of Columbia University, a learned man who, it is said, first taught in this country the nomenclature of Lavoisier, and Woodhouse, who in his quiet, just way endeavored to convince old Doctor Priestley of the erroneous nature of his views, but through the entire controversy maintained the happiest relations with this mighty Nestor in chemical science. One develops a strong affection for Woodhouse on observing his magnanimous attitude toward Priestley. Whatever faults he may have had, he surely was a man of sound judgment who thought long and well before acting. He was, it is true, very human, yet always quite ready to concede that the thoughts and views of others were entitled, at least to respect, hence it was not to be wondered that his friendship for Franklin's "heretic" was

unimpaired. This is beautifully exhibited in a record made by one of Woodhouse's students:

"I happened to be in Philadelphia, as a pupil of Dr. Woodhouse when Dr. Priestley came in person to the laboratory of Dr. Woodhouse, who was himself a disciple of Lavoisier, and who performed various experiments on this topic, at that time keenly controverted. It was the last effort to sustain the doctrine of phlogiston, and to produce from metals and inflammables a real substance, to which it was supposed that the name of phlogiston could be applied. Hydrogen had been before called phlogiston, but it was impossible to prove its existence in all inflammable bodies and metals (unless the discovery of this gas should establish it), and it was distinctly proved that it forms water by its combustion. Indeed, Dr. Priestley was one of the first to perform that interesting experiment, but he did not eventually admit the conclusion."

And Caldwell (p. 67) has expressly declared that in the earliest years of Woodhouse's laboratory activity it was along lines pertaining to the formation of water and its decomposition.

Did these early American chemists dream that as the years went on their problems, wrought with the expenditure of so much nervous and physical energy, would come to be

little regarded? The remarkable synthesis of an organic body—urea—from inorganic material, no longer excites astonishment when contrasted with the syntheses of sugar, alcohol, indigo, alkaloids, etc. And, so too, what was early executed in establishing the constitution of water fades away on studying such epoch-making researches as those of E. W. Morley and Theodore W. Richards, who in our own generation have built so superbly upon the early and crude efforts of Woodhouse and the men of his and immediately succeeding generations.

How will the conquests of the present be viewed by chemists one hundred years hence? Today it is generally thought that prevailing ideas and accepted work represent almost the final word. Doubtless the men of 1800 entertained very similar thoughts. They were wrong and we would find, on our return a century or two hence, if it were possible, the chemists of that far-away date, to be little excited over our efforts, considering them only as links in the great chain of inquiry leading to the Truth.

The phlogiston controversy on American soil was precipitated by Priestley himself. In 1796 he issued a pamphlet of thirty-nine pages bearing the title, "Considerations on the Doctrine of Phlogiston and the Decomposition of

Water." In this connection Mitchill remarked: "it must give pleasure to every philosophical mind to find the United States becoming the theatre of such interesting discussions." And further, "we feel a degree of satisfaction in ascribing a considerable part of the increasing taste and prevailing fashion for chemical pursuits in this country, within a year or two, to the influence and example of Priestley."

In his first paper, Priestley confessed that he had nothing particularly new to offer on the subject of phlogiston, but desired "to make one appeal more to the philosophical world," so he aimed to present as a complete picture the more important objections to the antiphlogistic system, "with the intention of bringing forward the favourers of the new doctrine, to the explanation of these difficulties, by the aid of additional *facts* and more cogent *arguments* that have hitherto appeared." Priestley had seen his friends and acquaintances deserting phlogiston, not merely one by one, but frequently going over to the other side in whole troops, while he remained firm to the doctrine of Stahl. As his views may be gleaned from the fasciculus noted above, they will not be here reproduced. Let it suffice to observe that a prompt reply came from Adet, the *ci-devant* Minister of the French Republic to

the United States, just before his departure from Philadelphia to France, which induced one writer to observe "we cannot but think he (Adet) has usefully employed the interval of leisure which the jarring politics of two governments afforded him."

Priestley's constant objection to the facts attending the composition and decomposition of water amazed Adet, for the anti-phlogistic chemists had repeated and verified the experiment so many times, and therefore he felt driven to state once again: "(1) that in causing water to pass through a red-hot gun barrel, the iron becomes oxydated by the oxygen of the water; (2) notwithstanding the difference which exists between the black oxyd of iron, produced by the decomposition of water, and the common red oxyd of the same metal, they are still both of them oxyds, for these reasons; that, like other oxyds, they both dissolve in acids without disengaging anything, and metallic bodies are incapable of combining with acids unless they are previously united to oxygen; (3) although there is some difference between this oxyd and the common red oxyd, it does not follow that they are not both oxyds; the difference between the two being only owing to the different circumstances under which they have combined with oxygen."

Adet asserted that all of Priestley's objections to the water problem were explainable without the introduction of the phlogiston idea. The participation in a chemical problem by one so eminent in diplomacy as Adet was justly esteemed a marked tribute to the science.

Another respondent to the brochure of Priestley was John Maclean, the honored professor of chemistry at Princeton. He had not been aware of Adet's communication. However, he deemed the subject of such importance that he placed his communication before his students in the course of his customary lectures. He answered Priestley, point by point. The zeal he exhibited will be best understood by reading his work. He confidently recommended the anti-phlogiston chemistry to his students in these words:

"From the view which has been given of the different explanations of the phenomena of combustion, it appears that Becher's is incomplete; Stahl's though ingenious, is defective; the antiphlogistic is simple, consistent, and sufficient; while Dr. Priestley's resembling Stahl's but in name, is complicated, contradictory, and inadequate. You, doubtless, therefore will be inclined to prefer the anti-phlogistic doctrine: Indeed, you may adopt it with safety; for, from being a plain relation of facts, it is

founded on no ideal principle, on no creature of the imagination; it is propped by no vague supposition, by no random conjecture; it is dependent upon nothing whose existence cannot be actually demonstrated; whose properties cannot be submitted to the most rigorous examination; and whose quantity cannot be determined by the tests of weights and measures."

Mitchill endeavored to reconcile the opposing views and the existing differences, but plainly was unsuccessful. In a compromising attitude he wrote Priestley "your opposition to the new doctrine has been serviceable to the cause of science. It has prevented too easy and sudden an acquiescence in the novel system of the antiphlogistians, where difficulties and paradoxes had been admitted by many, without having been subjected to due examination. You have prompted more vigorous inquiry into these matters than would probably otherwise have been made. . . . Perhaps even now my labors are but of little avail; or, if they were capable of bringing about a coalition of parties, I might say to you after all, in the words of Prior to his Alma:

> "For, Dick, if we could reconcile
> Old Aristotle with Gassendus,
> How many would admire our toil!
> And yet how few would comprehend us!"

Priestley wrote his thanks to Mitchill for his attempts to "promote a peace between the present belligerent powers in chemistry; but I much fear your labors will be in vain," and he adds that he would be obliged "if you will inform me when he (Maclean) replies to my last pamphlet. He did not treat me with the civility to which I think I am entitled as a veteran in the science. Had he been the victorious Buonaparte, I as an old Wurmser, should have been treated with respect, though vanquished. But this Mantua has not surrendered yet." And in a postscript wrote: "Dr. Maclean did not, as the laws of war require, ever send me a copy of his pamphlet; and as I never saw it advertised, it was only by the accident of my son's being in Philadelphia that I got it."

Priestley wrote at least eight letters in favor of the doctrine of phlogiston, practically repetitions of earlier arguments. To some of these Mitchill replied, always in the most apologetic vein, and with the earnest purpose of bringing an agreement among the opponents. "It would give me great satisfaction," he said on one occasion, "that we could settle the points of variance on this subject; though even as it is, I am flattered by your allowing my attempt to reconcile the two theories to be ingenious,

plausible and well-meant. Yet, after all I have written, I fear you still think they *cannot* be reconciled; consequently the labour of those who undertake it is thrown away; they toil to no purpose:

> In vain, tho' by their powerful art they bind
> Volatile Hermes, and call up, unbound,
> In various shapes, old Proteus from the Sea."

Maclean protested in a very animated fashion against the views of Priestley. The reader of the present will observe much animus in his remarks. It is difficult to explain this course unless he thought the observations, explanations, and experimental work of Priestley rather beneath his contempt.

Woodhouse had remained a silent observer of the course events took. He knew, as a matter of fact, everything that was going on, but was busily engaged in his laboratory, seeking evidence against the phlogistians. Priestley, having access to him in the midst of his work and probably contending on the spot with Woodhouse, the latter quickly learned to appreciate the genuine character of Priestley, and therefore could not be other than irritated by Maclean's writings. This state of Woodhouse's mind would easily explain the following epistle to Maclean:

"SIR,

"As there are several assertions in your examination of Dr. Priestley's consideration on the doctrine of phlogiston and decomposition of water, relating to some important parts of chemistry, which are absolutely erroneous, I think it necessary to call your attention to the subject.

"As you wrote your dissertation expressly to prevent the youth of Princeton college from falling even into temporary delusion, and as public controversy is always favourable to the cause of truth, you can have no rational objection to this letter.

"A judgment may be formed how well you have accomplished your purpose, and what right you have to condemn the experiments of Dr. Priestley in the authoritative manner you have done, having made none yourself, from the following particulars. You are not yet, Doctor, the conqueror of this veteran in philosophy.

"You agree with the French chemists, that turbith mineral is an oxyde of mercury, and have asserted, that any substance into which it may be converted by a red heat, does not require any addition to constitute it a metal.

"Now, the very contrary of this is true; for we have the most conclusive proofs, that turbith mineral is not an oxyde, but a sulphate of mercury.

"1st. If pure turbith mineral is exposed to a red heat, in a long glass tube, a quantity of the sulphate of mercury, of a white colour and strong acrid taste, sublimes from it, and adheres to the sides of the vessel.

"2dly. If a solution of caustic pot-ash is boiled upon the turbith, it suffers a considerable loss in weight, and loses its bright yellow colour, and is converted into a calx of the colour of brick dust. The solution, by spontaneous evaporation in the open air, will yield chrystals of vitriolated tartar.

"3dly. If distilled water is boiled upon the turbith, and renewed from time to time, the water will always precipitate a solution of muriated barytes.

"These experiments incontestibly prove, that turbith mineral is not an oxyde, but a sulphate of mercury.

"It is no objection to this opinion, that the turbith, when exposed to a red heat, yields oxygenous gas, and that running mercury is obtained; for the sulphuric acid leaves one part of it and joins to another, which sublimes in the form of a white salt. That part which the acid deserts is converted into an oxyde, is revived without addition and yields pure air.

"This sulphate of mercury is the supposed calx to which Dr. Priestley refers. It is some-

times obtained of a red colour, owing to some substance which deprives a part of the sulphuric acid of its oxygenous gas, and converts it into sulphur, which, uniting with the fluid mercury, sublimes in the form of cinnabar, and gives the whole of the salt a red colour.

"This is what you ought to have ascertained, if you intended to have acquired the character of an accurate investigator.

"Your next assertion is, that red lead contains more oxygene than a calx of iron, from which circumstance you suppose, that the former calx oxygenates the muriatic acid, and the latter does not, as it contains but a small quantity of pure air.

"Your words are: 'it certainly does not follow, because muriatic acid can separate a certain portion of oxygene from lead, when this is combined with a great quantity of this substance, that it should likewise separate oxygene from iron, when this is united to a comparatively small quantity.'

"You will grant, that when a pure metallic calx is heated in hydrogenous gas, that the oxygene of the calx unites to the hydrogene, and forms water; consequently those calces which make the greatest quantity of inflammable air disappear, contain the most oxygene.

"Having heated one drachm of red lead by

a burning lens, eleven inches in diameter, in hydrogenous gas; obtained from the sulphuric acid diluted with water, and malleable iron, and which had been well washed in lime-water, it made ten ounce measures of the air disappear.

"One drachm of the precipitate of iron, from green vitriol by ammoniac, or a solution of mild pot-ash and the common rust of iron, heated in the same manner, made thirty-six ounce measures of the air vanish. One drachm of the filings of bar-iron, melted in oxygenous gas, absorbed twenty-six ounce measures of this air.

"One hundred grains of well dried red lead, according to Lavoisier, contain 89.93 metal, and 7.64 oxygene; 25.39 water, and the same quantity of the precipitate of iron, from green vitriol, by caustic pot-ash, according to Gadolin, contains 58.48 metal, 15.91 oxygene. One hundred parts of the yellow calx of iron, according to Lavoisier, 68.66 metal, and 32.24 oxygene.

"Your opinion, then, according to these experiments, in regard to the quantity of oxygene which the calces of iron and lead contain, is void of foundation.

"The true reason that red lead will oxygenate muriatic acid, and that a calx of iron will not, is that the former readily gives it oxygene to the acid, and the latter does not, owing to a

difference in the elective attractions subsisting between the acid, oxygene and the two metals.

"It is evident, that the oxygenation of the muriatic acid does not merely depend upon the quantity of oxygene contained in the calx; for one drachm of manganese, which has been exposed to a red heat, and parted with most of its pure air, will oxygenate the acid to a greater degree than an ounce of the calx obtained from boiling a solution of the caustic alkali upon turbith mineral, which contains thirty times the quantity of oxygenous gas.

"You have also declared that Dr. Priestley is mistaken, in saying that finery cinder will not acquire rust, and assert that it contracts rust sooner than common iron.

"To determine this question a quantity of the scales which blacksmiths strike off from red-hot iron, reduced to an impalpable powder, were exposed to the action of the air more than twelve months, and were sprinkled with water several hundred times, and, at the end of this time, were as free from rust as when first exposed.

"The rust which finery cinder appears to contract is owing to iron filings with which it is frequently mixed. The pure scales will never acquire rust; for, when bar-iron is converted into finery cinder, it parts with the small

quantity of coal it contained, and absorbs oxygene and water.

"You have answered the Doctor, on this part of the controversy by informing him, that inflammable air is a constituent part of other bodies besides water; that hydrogene is retained with great force, by coal; that unglazed earthen vessels absorb moisture; and, lastly, you tell him in what manner the experiment ought to have been performed, and declare it is of no value, as reported in his experiments on different kinds of air.

"I have repeated this famous experiment, and the result is exactly as stated by Dr. Priestley.

"One ounce of the scales of iron, and the same quantity of charcoal, were separately exposed, in two covered crucibles, in an air-furnace, well supplied with fuel for five hours. They were then taken out of the fire, and mixed, while red-hot, in a red-hot iron mortar—were triturated with a red-hot iron pestle, formed of an iron ram-rod—were poured upon a red-hot piece of sheet-iron, and instantly put into a red-hot gun-barrel, which was fixed in one of Lewis's black lead furnaces, and communicated with the worm of a refrigeratory, a part of a hydropneumatic apparatus. Immediately after, luting the gun-barrel to the worm, one hundred

and forty-two ounce measures of inflammable air came over in torrents, mixed with a tenth part of carbonic acid gas.

"This experiment has puzzled every person to whom it has been mentioned.

"For my part, I do not think it affects the anti-phlogistic system, for the scales of iron contain water, and retain it in so obstinate a manner as not to part with it upon the application of heat; but when coal is added to the finery cinder, it takes away the water, by having a greater affinity to it than to the calx of iron. The coal decomposes this water; its oxygen is united to part of the coal, to carbonic acid; while its hydrogene is separated, dissolves another part of the coal, and forms the carbonated hydrogene gas.

"Dr. Priestley's explanation of this experiment is very unsatisfactory; for he says, the phlogiston of the charcoal contributes to revive the iron; but the Doctor ought to have remembered that an oxyde of iron cannot be revived in one of Lewis's small black lead furnaces.

"There are other substances besides finery cinder, which, when mixed with coal, which has ceased to yield air, give inflammable air in large quantities. It may be obtained from any precipitate of iron or zinc, or from the

flowers of zinc mixed with red-hot coal; and the hydrogene gas procured will always be in proportion to the water which the calces contain, and the metals will not be revived.

"Should you consider the objections of Dr. Priestley once more, and advance nothing but what is founded upon your own experiments, you may hear from me again; and I promise not to be the first to drop the subject.

"Mere assertions only serve to fix errors deeply in the mind, and do not advance the cause of truth.

"Hoping that I do not intrude upon the precious moments of your time, which is more agreeable, and, perhaps, more usefully employed than in discussing this subject,

"I am, Sir, with consideration,

"Yours, etc.

"James Woodhouse.

"Dr. John Maclean."

Maclean's answer to this communication was very unsatisfactory. It consisted of quibblings. It presented no new facts. Indeed, it was undignified, in witness whereof one needs merely to ponder the subjoined quotation; for it seems Woodhouse had emphasized his intention of pursuing Maclean unless he would offer real facts. So the latter said:

"At the same time be informed, you will write to one who is far from being a punctual correspondent; even his friends complain their letters are unanswered; so that, it is more than probable, he will take no notice of your criticisms.

"Do not understand from this that I mean to deter you from writing to me. Your letter has afforded me not a little entertainment; and, if you can always furnish me with the like, it will be very acceptable."

Woodhouse made no reply to Maclean. The latter dropped out of the controversy. As he had no convincing facts to submit, this was quite the proper thing for him to do. But with Woodhouse conditions were vastly otherwise. While following the discussions in print he was prosecuting, as has been said, his laboratory experiments unceasingly. He experimented and repeated experiments, as did Michael Faraday long after, when he strove to establish the fundamentals of electro-chemistry. He seemed possessed of but one thought, viz.—that experimental results, and these only, could give final decision upon the various topics brought forward in the discussions. Accordingly, he sent forth his observations in a memorable contribution, which constituted the 72d essay of the Fourth Volume of

the Transactions of the American Philosophical Society, from which it passed into other journals at home and abroad. Its purpose was to answer the arguments advanced by Priestley against the antiphlogistic system. The effort was made to review each point made by Priestley in its order of presentation.

He therefore discussed:

1st.—The revival of a metallic calx in inflammable air. "When the focus of a burning lens is thrown upon a calx of mercury, confined in hydrogenous gas, according to the antiphlogistic theory of chemistry, the oxygen of the calx unites to the hydrogen, and forms water; but, according to Dr. Priestley, the hydrogen enters into the metal, while the oxygen is found mixed with that part of the hydrogenous gas which remains behind.

"The Doctor declares, in support of this opinion, that, in several of his experiments, the pure air, expelled by the heat of the lens from the mercurial calx, was found mixed with the remainder of the inflammable air, as appeared by the test of nitrous air, and by some disagreeable explosions which happened in the process.

"Having performed the experiment of the revival of red precipitate in hydrogenous gas, twenty times, without having met with an

explosion, I concluded that Dr. Priestley's inflammable air must have been mixed with atmospheric air. I was of this opinion, because I never could detect any pure air mixed with inflammable air, after the revival of a mercurial calx in it, by the test of nitrous air."

2d.—The calcination of a metal in pure and "atmospherical" air.—The oxygen employed in the many experiments under this rubric was exceedingly pure, because "the whole of it was devoured by the nitrous test."

3d.—Carbonic acid or fixed air. This was really a consideration of the various means of preparing "fixed air." Priestley had said "that large quantities of it could be obtained from heating a mixture of iron filings and red precipitate," concluding with the statement that the experiment had never failed with him, to which Woodhouse rejoined—"and I say it has *never* succeeded with me" . . . and adds, "in my opinion, the proofs that fixed air (CO_2) is composed of oxygen and carbon, are as strong as that Glauber's salt is composed of sulphuric acid and soda." It seems that Priestley had said that fixed air was composed of "inflammable air" and "dephlogisticated" air, which prompted Woodhouse to ask then, "why is it not obtained by exploding pure air and the 'inflammable' air from malle-

able iron?" He showed that if Priestley really got "fixed air" in this way it was because the "inflammable air" from cast iron filings "holds coal [carbon] in solution."

4th.—Finery cinder or the scales of iron. This substance seemed to have vexed many chemists. Woodhouse knew that fixed air and "carbonated inflammable air" resulted upon heating it with charcoal; he therefore wrote:

"In considering what takes place in this process, we must call to our aid the decomposition of water, the clue which leads us through all the labyrinths of the antiphlogistic system of chemistry. The carbonated inflammable air is formed by the hydrogen of the water, which is supplied by the finery cinder, dissolving part of the coal [carbon], while the oxygen of the water and finery cinder, uniting with another part of the coal, make the fixed air.

"We are under the necessity of admitting the presence of water in the finery cinder. It cannot be in the coal, where Berthollet, Fourcroy, and other chemists find it; for, in my experiments, the coal has ceased to yield air, and, consequently, could not contain water."

To explain this he thought he was obliged to admit the presence of water in the finery cinder.

5th.—Here he described "the precipitation of one metal by another" and cited the fact that when zinc is introduced into a solution of sugar of lead "inflammable air is produced." He observed that he also got the air by the interaction of zinc filings and copper sulphate, etc. He declared the French chemists were ignorant of this.

6th.—Here Woodhouse remarked in connection with the air contained in the pores of charcoal which has been exposed to a red heat:

"Dr. Priestley says that charcoal contains azotic gas, but I have always found it to be atmospherical air. One measure of the air obtained from coal, by means of water, gave, with the nitrous test, an absorption of 90."

Much excellent experimentation was presented in Woodhouse's argumentation upon the preceding topics. All that he did possessed a pronounced bearing and value in arriving at the truth.

Close upon this document came letters addressed to the editors of the *Medical Repository* in which were presented additional observations to certain objections made by Priestley to the antiphlogistic system of chemistry. He said at the outstart that mistakes may have been made by Priestley as well as by the French, and "should any be made by myself, I shall

always acknowledge them, for nothing is more desirable than truth in science. Following the laudable example of Dr. Priestley, I shall endeavor to imitate his well-known candor and strict adherence to matter of fact—

> "Non ita certandi cupidus, quam propter amorem
> Quod eum imitari aveo."—LUCRET.

After which he resumed the old subject of "the calces of metals and coal exposed to a red heat." He continued to maintain the presence of water in "finery cinder" giving his experimental proofs, and saying that "oxygen is also one of its component parts, which Dr. Priestley will not allow." The patience exercised in the execution of innumerable experiments is astounding. The constant resort to quantitative conditions is also striking and highly creditable. Every student of chemistry will admire these important features of Woodhouse's effort. It is an exhaustive study. It was most meritorious although in many points it led to erroneous views or conclusions. Various oxides were mixed with coal and then heated. The results were given in the utmost detail. Curiously enough, he writes at one place:

"The flowers of zinc, yielding no fixed air when subjected to heat with coal, or the fixed

air which is sometimes obtained being in proportion to the water, which is united to the calx, is agreeable to the theory of Dr. Priestley, and cannot be accounted for as vitriolic acid and water were added to it, to dissolve any particles of iron it might contain, and it was well washed in pure water.

"The focus of a lens was thrown upon a portion of this metal, confined in fifty-six ounce measures of oxygenous gas, which had been washed in lime water, and was of the purity of 155, until nineteen ounce measures were absorbed. The remaining air was of the purity of 140, and contained $\frac{1}{100}$ parts fixed air.

"The copper calcined in this operation was then revived, by heating it in forty-eight ounce measures of hydrogenous gas, from malleable iron, when eighteen ounce measures of the air disappeared. The remainder of the inflammable air contained no fixed air.

"The revived metal was then melted in fifteen ounce measures of pure air, of the strength of 140, until eight ounce measures were absorbed. The remaining air was of the purity of 125, and contained $\frac{1}{10}$ parts fixed air. The calcined metal was again heated in forty-four ounce measures of hydrogenous gas, until sixteen ounce measures disappeared. The remaining air contained no fixed air."

Other metals were experimented upon in a similar manner, when Woodhouse said:

"When fixed air is generated by heating in pure air copper, which has been revived by inflammable air from the calx of copper . . . the only source of coal can be from particles of dust which accidently became mixed with the copper, and which it is difficult to exclude. The disinterested must decide whether this explanation is completely satisfactory."

Other subjects of discussion were the effect of "hydrogenous gas" on fresh manganese, and upon that oxide remaining after the expulsion of its "pure air." Again, he was successful in refuting the thought of Priestley. The effect of heating finery cinder in "carbonated hydrogenous gas" was another problem from which Woodhouse came victorious, bringing with him facts of great interest to all chemists. Thus the controversy proceeded with the honors falling in almost all instances upon the young American investigator.

The controversial activity of Woodhouse must certainly have interested his students. They witnessed the experiments and doubtless discussed the various lines of argument. Only

one, as far as can be learned indirectly, referred to the work. This hint has been already given on p. 123. For a portion of this period of storm and stress Robert Hare was under the tutelage of Woodhouse, but nowhere in his writings does one discover any reference to the subject which so completely absorbed the thought of his elders. Perhaps, his own devotion to the remarkable behavior of hydrogen and oxygen overshadowed all else. It was his effort to improve the ordinary blow-pipe which eventually culminated in the oxyhydrogen flame torch, but who knows but that his daily contact with hydrogen and oxygen, as they were handled by Woodhouse, may have been the unconscious force which prompted him to apply their use? However, the atmosphere about him and about all other American chemists was being quite rapidly filled with other ideas. Volta had evolved his battery. Dalton had just enunciated, among a wide circle of friends, his views relative to atoms and their combination with one another; and the various participants in the great struggle were strong in their convictions with reference to the soundness of the views of Lavoisier and his followers, so that interest in the stoutly maintained ideas of Priestley began to wane and contestants gradually directed their endeavors to other fields.

At last, Priestley, weary of the contest, declares that he had become too old to wage further war, but that he thought there remained still some unsettled points, the explanation and elucidation of which he willingly assigned to his much younger and more aggressive antagonist, who was so amply equipped for this final task. Thus practically ended the memorable contest which had extended itself through so many years. Woodhouse, however, appears to have been deeply stirred by Priestley's final declarations on "Phlogiston Established" and was averse to letting them pass without a final word from himself. Granting much to his adversaries, he continues steadfast in his early views, so that while his concluding document is somewhat lengthy it must be given inasmuch as it represents Woodhouse's final thoughts, and the results of numerous and tedious experiments. He styles the contribution an answer to Priestley's ideas on the doctrine of phlogiston, and the decomposition of water, but plainly aims to make his views as conclusive as possible by adding that what he announced was "founded upon demonstrative experiments." He discusses the subject by topics; thus,

"1. Of the Constitution of Metals.

"Dr. Priestley, in two publications, attacked that theory of chemistry, which is at present

adopted by a large majority of chemists, in different parts of the world.

"The doctor adheres to the doctrine of phlogiston, and believes that metals are compound bodies, formed of this substance and a peculiar base or calx.

"On the contrary, the antiphlogistic chemists reject phlogiston.

"First. Because it appears to be a mere creature of the imagination, whose existence has never been proved.

"Secondly. Because all the phenomena of chemistry, can be satisfactorily explained, without the aid of this hypothesis.

"They believe metals to be simple substances, because they have never been proved to be compound bodies.

"They consider a metallic calx, to be a union of a metal and the base of a vital air, called by them oxygen, as it is the principle of universal acidity. The proofs that metals in being converted into calces, absorb oxygen, are,

"First. That all calces of mercury give out oxygenous gas when exposed to a red heat, without any addition.

"Secondly. If a metal is calcined in oxygenous gas, the whole of it will be absorbed.

"Thirdly. If the process of calcination is performed in a variety of gases, containing some

oxygenous air, the oxygen only will be imbibed by the metal, and the others will be left unaltered.

"Fourthly. If any substance is added to a metallic oxyd, and the calx is revived, a compound body will be produced, formed of the agent used and the oxygen contained in the calx.

"Thus, if the filings of pure bar iron are mixed with red precipitate, and exposed to a red heat, the iron will be converted into a calx and the mercury will be revived. If pure charcoal is mixed with the precipitate, carbonic acid will be produced; and if the mercurial calx is revived in hydrogenous gas, water will be formed.

"The first objection of Dr. Priestley, to this theory of the calcination of metals, is as follows:

"He says, if turbith mineral is exposed to a red heat, a calx remains which cannot be revived in any degree of heat, without the aid of some substance, supposed to contain phlogiston. Before we proceed any further in this investigation, it is absolutely necessary to determine the real composition of turbith mineral.

"According to the French philosophers, this substance is a pure oxyd of mercury.

"Fourcroy and Baumé declare, that it does not contain one particle of sulphuric acid. Dr. Priestley is doubtful whether it is a salt

or a calx; and in the Edinburgh Dispensatory and London Pharmacœpia Chirurgica, it is called hydrargyrus vitriolatus flavus.

"The following experiments were made, to ascertain the composition of this substance:

"First. One ounce of pure turbith mineral was exposed to a red heat, in a long glass tube, which communicated with an hydropneumatic apparatus, when thirty-three ounce measures of oxygenous gas were obtained. Upon breaking the glass, a quantity of fluid mercury was found in the tube. Two drachms of the sulphate of mercury, of a white colour and a strong acrid taste, had sublimed on the sides of the glass. A part of the sulphate of mercury, was coloured by an immense number of minute particles of revived mercury, which gave it the appearance of mercurius cinereus.

"Secondly. One ounce of turbith mineral, was boiled fifteen times, six hours each time, in half a pint of distilled water, which was renewed every time; and it could not be freed from the sulphuric acid, for the water always precipitated a solution of muriated barytes.

"Thirdly. One ounce of turbith mineral was boiled three hours in a solution of caustic pot-ash, when it lost its yellow colour, and was converted into a calx of the colour of brick dust. Upon being dried it was found

to have lost one hundred and sixty grains in weight.

"The liquor in which it was boiled by spontaneous evaporation in the open air, gave chrystals of vitriolated tartar.

"These experiments were repeated with turbith mineral, made by precipitating a solution of the sulphate of mercury by pot-ash, with the same result.

"They clearly prove, contrary to what has been advanced by Lavoisier, Monnet, Bucquet, Fourcroy, Chaptal and other French chemists, that turbith mineral, is not a pure oxyd of mercury, but contains sulphuric acid, and may be considered as a sulphate of mercury.

"The reason that those gentlemen were deceived in regard to the composition of this substance must have been, either that they did not break the vessels in which their experiments were made, to discover any residuum, or from the circumstance, of obtaining oxygenous gas from the turbith, equally as good as from any acknowledged calx of mercury.

"The reason that turbith mineral yields oxygenous gas, when it is exposed to red heat, is, that the sulphuric acid quits one part of it and joins to another, which sublimes in the form of a white salt. That part which the sulphuric acid leaves, is converted into a calx,

is revived without addition, and yields oxygenous gas.

"Thus sulphate of mercury is the supposed calx to which Dr. Priestley refers. It is sometimes obtained of a red colour, owing to some impure matter contained in the turbith mineral, which by depriving a part of the sulphuric acid of its pure air, converts it into sulphur, which uniting with part of the revived mercury, forms cinnabar, which gives the whole of the sublimed salt a red colour.

"That it is a sulphate of mercury, we have an additional proof, from an experiment of Dr. Priestley, for he procured ethiops mineral, by heating this supposed calx in inflammable air, by means of a burning lens, which he could not have obtained from a pure calx of mercury, treated in the same manner.

"The size of the vessel, in which turbith mineral is heated, will vary the result of the experiment. No residuum can be obtained by exposing it in a crucible to a red heat, for the whole of it flies away, and leaves only a mark on the bottom of the vessel. The same circumstance will take place, if a short glass tube is used.

"Having thus determined, that the substance which remains after exposing turbith mineral to a red heat, is a neutral salt, coloured red by

cinnabar, and not a metallic calx, we see that the first objection of Dr. Priestley, to the theory of the calcination of metals, adopted by the antiphlogistic chemists, loses all its force, for certainly it does not follow, that because the sulphate of mercury requires to be deproved of its sulphuric acid, before running mercury can be procured from it, that therefore all mercurial calces require the addition of phlogiston, to be converted into mercury.

"The second objection of Dr. Priestley, to the new theory of chemistry is, that when a metal is reduced to a calx, it throws out something which forms phlogisticated air. He says, that when the focus of a burning lens, is thrown upon iron confined in atmospheric air, the dephlogisticated air is not merely separated from the phlogisticated air, but that the phlogiston from the iron, unites with the dephlogisticated air, and forms azotic gas.

"In order to see if this assertion was just, the focus of the burning lens belonging to our society [Chemical Society of Philadelphia], which is eleven inches in diameter, was thrown upon ninety grains of the filings of bar iron, filed for the purpose, confined in thirty-two ounce measures of oxygenous gas, which had been well washed in lime water, and which was so pure, that nearly the whole of it was devoured

by the test of nitrous air. Twenty-eight ounce measures of the pure air were absorbed by the iron, which was reduced to a calx.

"The quantity of carbonic acid produced, which was formed by a small quantity of coal, which all iron of commerce contains, uniting to a part of the pure air, amounted to one ounce measure.

"When the fixed air was absorbed by washing it in lime water, the remaining air was in no manner injured.

"The focus of the lens was likewise thrown, upon sixty grains of the filings of copper, confined in sixteen ounce measures of oxygenous gas. Twelve ounce measures of the pure air were absorbed by the metal, which was converted into a calx. No carbonic acid or azotic gas was formed, and the remaining air was perfectly pure. These experiments prove, contrary to what has been said by Dr. Priestley, that when a metal, containing no foreign substance, is calcined in oxygenous gas, the pure air only is imbibed, no substance is emitted from the metal, and no azotic gas is formed.

"2. Of the Solution of Iron in the Diluted Sulphuric and Muriatic Acids.

"The next thing which engages the attention of Dr. Priestley, is the solution of iron, in the diluted sulphuric and muriatic acids.

"The question to be decided is, whether the hydrogenous gas, which is produced, comes from the iron, or from the water which the acids contain.

"The antiphlogistic chemists contend, that it comes from the water, for the following reasons:

"First. If concentrated sulphuric acid is boiled upon iron filings, sulphurous gas is produced, but no inflammable air, and the sulphuric acid suffers a decomposition and a loss in weight.

"Secondly. If the sulphuric acid is digested upon iron in the cold, it remains in a quiescent state, but the instant water is added, a violent action ensues, accompanied by a discharge of hydrogenous gas.

"Thirdly. They believe that the hydrogenous gas comes from the water, because no inflammable air, can be produced from iron without water, and the hydrogenous gas obtained is in strict proportion to the water, which the acids contain.

"Fourthly. They believe, water is decomposed in dissolving iron in the diluted sulphuric acid, that its oxygen calcines the metal, while the hydrogen escapes, and that the acid acts upon the calcined metal without being decomposed, for it will saturate as much alkali,

after the process of solution, as it did before.

"Fifthly. They prove that water is composed of oxygen and hydrogen.

"Dr. Priestley's objection to this explanation is, that as one hundred parts of water, according to the advocates of the new system of chemistry, are composed of eighty-seven parts of oxygen and thirteen of hydrogen, which is nearly seven times as much of the former as of the latter, there must be a great deposition of oxygen somewhere, when iron is dissolved in diluted sulphuric acid, which he cannot discover.

"He denies that it unites to the metal, and declares there is no addition of oxygen in the process, and consequently that there is no decomposition of water in the case.

"That there is a quantity of oxygen, which unites to the metals, when dissolved in acids, I think can be easily proved.

"In order to do this I will shew, that when pure metallic calces, which are acknowledged by Dr. Priestley to contain oxygen, are heated in hydrogenous gas, that the oxygen of the calces unites to the hydrogen and forms water, and that the disappearance of the inflammable air, is always in strict proportion to the pure air which the calces contain.

"I will then prove that the calces of copper and iron, obtained from the sulphates of these

metals by ammoniac, have this property of making large quantities of inflammable air disappear. The oxyds which are acknowledged to contain oxygen are mercury, lead and manganese.

"The focus of the lens was thrown upon two drachms of red precipitate, confined in thirty-two ounce measures of hydrogenous gas, obtained from the sulphuric acid diluted with water and the filings of bar iron, which had been well washed in lime-water. Twenty-two ounce measures of the inflammable air disappeared, the mercury was revived and no carbonic acid gas was produced. The air which remained behind was not altered.

"According to Dr. Priestley, fixed air should have been formed in this process, for he says, when any substance known to contain oxygen, is heated in inflammable air, fixed air is found, but this is not the case.

"I agree with the Doctor, that carbonic acid gas will be obtained by reviving minium, or mercurius precipitatus per se in inflammable air, for these calces generally contain it, but if the minium be converted into massicot, no fixed air will be generated.

"Here we have a strong proof of the position we are endeavouring to establish.

"Two drachms of red lead, make twenty

ounce measures of inflammable air disappear, when heated in it by the burning lens, but when converted into massicot, only eight ounce measures.

"Now, if Dr. Priestley's theory was true, that the metal imbibed the air, massicot ought to absorb more inflammable air than minium, as it contains more lead than an equal weight of minium.

"In making red lead into massicot, nothing but pure air with a small quantity of fixed air escapes, and the loss of the pure air is the true reason, that one calx of the same metal, will make more inflammable air disappear than another.

"But we have still stronger proofs, to prove that our ideas on this subject are just.

"The focus of the lens was thrown upon one drachm of the oxyd of manganese, confined in thirty ounce measures of hydrogenous gas, when twenty-two ounce measures of the gas disappeared, and the metal was not revived. How then could the inflammable air have entered into its composition?

"A quantity of the oxyd of manganese, was exposed to a red heat for three hours, and a part of its pure air was driven off, when upon throwing the focus of the lens upon one drachm of it confined in inflammable air, none of the

air disappeared, whereas if this quantity of the oxyd, had not been exposed to a red heat, twenty-two ounce measures of the air would have vanished.

"Some manganese was also precipitated from its solution, in the muriatic acid by ammoniac, and when fresh made it would never make any inflammable air disappear, when heated in it by the burning lens, but after being exposed a few days to the action of atmospheric air, one drachm of it made four ounce measures of inflammable air disappear. In all these cases we evidently see the operation of oxygen. Not knowing the exact quantity of pure air, which iron and copper absorbed, one drachm of the filings of bar iron were melted by the burning lens in oxygenous gas when twenty-six ounce measures were imbibed by the iron, and the same quantity of the filings of copper heated in the same manner gave an absorption of thirteen ounce measures.

"One drachm of the precipitate of iron, from a solution of the sulphate of iron by ammoniac, was then heated in forty-six ounce measures of hydrogenous gas, when thirty-six ounce measures of the air disappeared.

"The same quantity of the common rust of steel, and the carbonate of iron, obtained from green vitriol by a solution of mild *pot-ash*,

and what Dr. Priestley calls a nitrated calx of iron formed by adding nitric acid to a calx of iron and exposing it to a red heat, when treated in the same manner, made exactly as much air vanish.

"One drachm of the precipitate of copper, from a solution of blue vitriol by ammoniac, exposed to the action of the lens in hydrogenous gas, made eighteen ounce measures of the air disappear.

"Here then are two metals, one of which the iron, absorbs twice as much oxygen, when melted in it, as the copper, and its calx following the same proportion when heated in hydrogenous gas, makes exactly twice as much of the air disappear.

"After one drachm of the calx of iron, had made thirty-six ounce measures of inflammable air disappear, it was exposed to the action of the lens in oxygenous gas, when four ounce measures of the air were absorbed, and after this being again heated in hydrogenous gas, six ounce measures of the air vanished.

"In all these experiments nothing but water was produced. The carbonic acid gas was not obtained, unless it previously existed in the calces.

"It is not however denied, that fixed air

may be generated by heating a pure metallic calx, in a particular kind of inflammable air. Thus it may be made by reviving red precipitate in hydrogenous gas, obtained from exposing the flowers of zinc and coal to a red heat, or from passing alcohol over red hot iron, but none will be procured from that made by the diluted sulphuric acid and malleable iron, or from that obtained by passing the steam of water over malleable iron.

"Upon reviving three drachms of red precipitate, in thirty-six ounce measures of hydrogenous gas, from the flowers of zinc and coal, which had been well washed in lime water, there was an absorption of only two ounce measures.

"After the operation, there was a great production of carbonic acid gas. Water was not formed in this process, for the coal held in solution in the hydrogenous gas, had a stronger attraction to the pure, than to the inflammable air, and consequently fixed air was generated.

"Had the same quantity of precipitate been revived in inflammable air, from malleable iron, upwards of thirty ounce measures of the air would have vanished.

"Dr. Priestley, supposing that the inflammable air, or the phlogiston it contains, enters

into the composition of metals, has made a calculation of the quantity of this air absorbed by an ounce of several of them. He calculates from the metal actually revived. According to him, one ounce of mercury absorbs three hundred and sixty-two ounce measures of hydrogenous gas. The quantity mentioned here, is far too great. One drachm of red precipitate, which contains more than fifty grains of mercury, makes twelve ounce measures of inflammable air disappear.

"It is a difficult matter to be exact in this experiment, for some of the precipitate always disperses in reviving the mercury, and a part of the metal sublimes, and adheres to the sides of the vessel which is used.

"As I believe, that when a metallic calx is heated in hydrogenous gas, the oxygen of the calx, unites to the hydrogen and forms water, I always calculate from the quantity of hydrogenous gas that disappears, from heating a given quantity of a calx in this air.

"According to my experiments, one ounce of red precipitate, mercurius precipitatus per se, and the calx obtained by boiling a solution of caustic pot-ash in turbith mineral, makes 112 ounce measures of inflammable air disappear, when heated in it by burning lens.

Red Lead	88
Massicot	32
Litharge	32
Manganese	192
Copper	144
Iron	288

"Upon dissolving half a drachm of the precipitate of iron, which had made sixteen ounce measures of hydrogenous gas disappear, in diluted sulphuric acid, as much inflammable air was obtained, as two grains of the filings of malleable iron would have produced. According to this experiment, were I to calculate in the same manner as Dr. Priestley, I would say, that one ounce of bar iron absorbs 3,840 ounce measures of inflammable air, but this quantity of the metal by solution in the sulphuric acid and water will yield no more than 365 ounce measures of hydrogenous gas.

"If an ounce of mercury absorbs 362 ounce measures of inflammable air, it ought to give out this air when dissolved in an acid, or some substance into which it enters as a constituent part. But mercury revived from red precipitate by inflammable air, boiled in sulphuric acid gives sulphureous gas, and when added to nitric acid, nitrous air, neither of which contains inflammable air.

"It should also exhibit some properties,

when subjected to the action of chemical agents, different from that which is revived from a mercurial calx merely by an increase of its temperature, which is not the case; and if mercury absorbs inflammable air, that which is revived without addition, when heated in inflammable air should absorb some of it which it will not do.

"It certainly is not probable, that an ounce of mercury containing more than twelve quarts of hydrogenous gas, should have the same external appearance, and exhibit the same chemical properties, as that which does not contain one particle of this air.

"Dr. Priestley not only believes, that when red precipitate is heated in hydrogenous gas, the inflammable air enters into the metal, but that, the pure air of the metallic calx is diffused through the hydrogenous gas which remains behind.

"As a proof of this he mentions an explosion, which happened from reviving red precipitate, in inflammable air. I have performed this experiment with different proportions of red precipitate, twenty times, and have never met with any accident (p. 140).

"The inflammable air that Dr. Priestley used, must have been mixed with atmospheric air, or an explosion would not have happened.

That the pure air of the metallic calx is not diffused through the inflammable air which remains behind, appears evident from the following circumstances.

"If one drachm of red precipitate, is revived in sixteen ounce measures of hydrogenous gas, twelve ounce measures of the inflammable air will disappear, and the remaining four ounce measures, will not be diminished by the test of nitrous air.

"This circumstance has happened in some of the experiments of Dr. Priestley.

"Another objection brought forward by Dr. Priestley is, that if hydrogen be nothing more than a component part of water, it never would be produced, but in circumstances in which either water itself, or something into which water is known to enter is present. He tells us, that upon heating finery cinder together with charcoal, inflammable air is produced, though according to the new theory no water is concerned.

"The antiphlogistic chemists never said, that hydrogenous gas could not be produced without water; for it is a constituent part of other bodies, as alcohol and ammoniac.

"To ascertain the quantity of hydrogenous gas, afforded by charcoal and finery cinder exposed to a high degree of heat, an ounce of

the scales of iron and the same quantity of charcoal, both reduced to a very fine powder, were separately exposed in covered crucibles, in an air furnace, well supplied with fuel, for five hours. They were then taken out of the fire, and mixed while red hot in a red hot iron mortar, triturated with a red hot pestle, formed of an iron ramrod, were poured upon a red hot piece of sheet iron, and instantly put into a red hot gun barrel, which was fixed in one of Lewis's black lead furnaces, and which communicated with the worm of a refrigeratory, a part of a hydropneumatic apparatus. Immediately after luting one end of the gun barrel to the worm, one hundred and forty-ounce measures of inflammable air came over in torrents, mixed with one-tenth part of carbonic acid gas (p. 136).

"This experiment has puzzled all the advocates of the antiphlogistic system, to whom it has been mentioned. Many consider it as a powerful blow at the new doctrine, and every person explains it in a different manner.

"Dr. Priestley's theory of it is very unsatisfactory, for he says that the water from the finery cinder, uniting with the charcoal makes the inflammable air, at the same time that part of the phlogiston from the charcoal contributes to revive the iron.

"This explanation will not do, for the iron is not revived, and it will not account for the production of carbonic acid.

"By considering the scales of iron, as a combination of iron, oxygen and water, there will be no difficulty in the business. The finery cinder supplies the coal with water, which is decomposed; its oxygen unites with the coal and forms carbonic acid, while its hydrogen escapes, dissolves part of the coal, and forms the carbonated hydrogen gas.

"The celebrated Mrs. Fulhame, a lady whom I am proud to quote on this occasion, is the only person I know, who seems properly impressed with the idea of the agency of water, in many chemical operations. This distinguished lady, who is equally an example to her sex, and an ornament to science, has properly considered a metallic oxyd as a combination of a metal, oxygen and water.

"There are other substances besides finery cinder, which mixed with coal and exposed to a red heat, yield hydrogenous gas and carbonic acid, in large quantities. These airs may be obtained from the common rust of iron, or from any precipitate of iron, and coal which has ceased to yield air. They may also be procured from the flowers of zinc, and red hot coal.

"One drachm of the flowers of zinc and twelve grains of red hot coal, which had ceased to yield air, being exposed to a red heat gave forty-eight ounce measures of hydrogenous gas, every portion of which was mixed with some carbonic acid.

"One drachm of the precipitate of zinc, from a solution of white vitriol by ammoniac, exposed to a red heat half an hour, when mixed while red hot, with red hot coal, which had ceased to yield air, gave fourteen ounce measures of inflammable air, mixed with carbonic acid.

"The flowers and precipitate of zinc in these cases, supplied the coal with water which was decomposed. The metal was not revived.

"3. Of Finery Cinder of the Scales of Iron.

"The antiphlogistic chemists consider the scales, which blacksmiths strike off from red hot iron, to be iron partially oxygenated.

"On the contrary, Dr. Priestley supposes, that when iron is heated in oxygenous gas, it parts with its phlogiston, and is converted into a substance resembling finery cinder, but he will not allow that the air which disappears in this process, is imbibed in the iron, but only the water which is its base, while the oxygenous gas, he says, always goes to form the fixed air which is found in the experiment.

"He declares that the quantity of carbonic

acid, is quite sufficient to take all the oxygenous gas that disappears in this process.

"That the Doctor's ideas are not just on this subject, we have the most conclusive evidence.

"If half a drachm of the filings of bar iron, are melted in twenty ounce measures of pure air, thirteen ounce measures of the air will be absorbed by the iron, which will be converted into finery cinder. Half an ounce measure of carbonic acid gas will be produced.

"Lavoisier tells us, if the iron is pure, no fixed air will be obtained; and certainly Dr. Priestley will not say, that thirteen ounce measures of oxygenous gas enter into the composition of half an ounce measure of fixed air, which must be the case if his theory is true.

"Here then are twelve and a half ounce measures of pure air, which cannot be accounted for according to the system of Dr. Priestley, and when we see a substance produced, by melting iron in oxygenous gas, resembling the scales of iron in every property, and cannot account for the air which disappears but by supposing it is imbibed by the iron, can we hesitate to pronounce, that the scales of iron contain oxygen?

"The Doctor likewise supposes, that if oxygen was lodged in a calx of iron, it would dephlo-

gisticate the muriatic acid which minium instantly does, and which we grant does not contain a third as much pure air as a calx of iron.

"To determine if finery cinder would dephlogisticate the muriatic acid, four ounces of the acid, were distilled upon three ounces of the powdered scales of iron, without success.

"An attempt was also made to dephlogisticate the acid, by distilling two ounces of the sulphuric acid, upon three ounces of common salt, and as much of the scales of iron, without effect. The quantity of oxygen contained in these scales, must have been several hundred measures.

"These trials however do not invalidate anything which has been advanced by the antiphlogistic chemists, for the oxygenation of the muriatic acid, does not depend so much upon the quantity of pure air contained in a calx, as upon its readiness to give out this air to the acid; when the attraction between the oxygen and metal is greater than between the oxygen and the acid, the acid will not be oxygenated. This is the case with iron.

"A proof that the oxygenation of the muriatic acid, does not depend merely upon the quantity of oxygen contained in a calx is, that a drachm of manganese, which has been exposed several hours to a red heat, and parted with the greatest

part of its pure air, will oxygenate the muriatic acid to a greater degree, than one ounce of mercurius cinereus, or the calx obtained by boiling caustic alkali upon turbith mineral, which contains thirty times as much pure air.

"The Doctor likewise observes, if finery cinder was iron partially oxygenated, it would go on to attract more oxygen from the atmosphere, and in time be converted into a rust of iron.

"In order to determine if finery cinder would attract oxygen, the focus of the lens was thrown upon a quantity of it, confined in pure air, which was not absorbed.

"The steam of water was also passed over it for several hours, when red hot in an iron tube, but it suffered no alteration.

"One ounce of it reduced to a fine powder, was exposed to the action of atmospheric air upwards of twelve months, and sprinkled with water several hundred times, and at the end of this time, was as free from rust, as when first exposed, while an ounce of iron filings moistened with water, were covered with rust in three days.

"I acknowledge that finery cinder cannot be converted into rust, but cannot see in what manner this makes against the antiphlogistic system. When bar iron is converted into finery cinder, it parts with the small quantity

of coal it contained, and absorbs oxygen and water.

"The rust of iron differs from it materially, for it contains a portion of carbonic acid, and although the French chemists consider this preparation as a carbonate of iron, I do not think it is entitled to this appellation, for one ounce of it yields but four ounces of fixed air, whereas the same quantity of the precipitate from green vitriol by the common pot-ash of the shops, yields thirty-two ounce measures, and deserves this character with more propriety.

"A strong proof that finery cinder contains oxygen is, that when it is heated in hydrogenous gas, it makes a large quantity of it disappear, and I have shewn, that when metallic calces are heated in this air, that the disappearance of the inflammable air, is always in strict proportion to the pure air which they contain.

"4. Of Carbonic Acid or Fixed Air.

"According to the advocates of the anti-phlogistic system, the carbonic acid or fixed air, is a combination of charcoal and oxygen. They are of this opinion for two reasons.

"First. If charcoal be plunged in a vessel of oxygen gas, the whole of it will be consumed, and carbonic acid gas will be produced.

"Secondly. It is well known, that all the calces of mercury may be reduced without any

addition and will afford oxygenous gas, but if charcoal be mixed with them, the carbonic acid gas will be formed, and the charcoal will be consumed.

"Dr. Priestley, in opposition to this opinion, declares, that large quantities of fixed air have been procured in his experiments, where neither charcoal nor anything containing it was concerned.

"He says, when the purest malleable iron is heated in dephlogisticated air, a considerable quantity of fixed air is formed. He tells us, in the first edition of his works, that there is but a small portion of fixed air, formed in this process.

"Four experiments were made to determine this question.

"Melting by the burning lens, half a drachm of the filings of bar iron, filed for the purpose, in twenty-four ounce measures of oxygenous gas, which had been well washed in lime water, eleven ounce measures of the air were imbibed by the metal, and half an ounce measure of carbonic acid gas was produced.

"One drachm of the same kind of filings, melted in thirty-six ounce measures of oxygenous gas, gave one ounce measure; one drachm and a half, an ounce and the eighth of an ounce measure; and two drachms, one

ounce and the sixth part of an ounce measure of carbonic acid gas.

"One ounce of this iron in small pieces, dissolved the sulphuric acid and water, left a residuum of one-half grain of charcoal.

"There was evidently then not a sufficient quantity of coal, contained in this iron, to account for the carbonic acid produced, by melting the iron in oxygenous gas, according to this analysis, which is certainly, not imperfect.

"The inflammable air, produced by dissolving bar iron, in diluted sulphuric acid, holds a portion of charcoal in solution, which is not easily detected, owing to the very small quantity of coal, being equally diffused through a large quantity of hydrogenous gas, for the portion of coal cannot be more than three grains, in three hundred and sixty-five ounce measures of inflammable air.

"That the carbonic acid produced in this process, does actually proceed from the charcoal contained in the metal, we have the most conclusive proofs, for the quantity of it obtained, is always in proportion to the coal obtained in iron.

"Bar iron contains a very small quantity of coal, compared to cast iron, and by heating cast iron in hydrogenous gas, much more carbonic acid may be produced than from bar-iron.

"Dr. Priestley says, that the plumbago contained in iron, could not be disengaged from it in this process, and if it could, it would not yield the hundredth part of the fixed air that is produced.

"The charcoal contained in plumbago, can certainly be disengaged from it with the greatest ease, for every particle of it, is exposed to a high degree of heat in oxygenous gas.

"Two other arguments used by the Doctor, to prove that fixed air may be procured without charcoal, are:

"That a great quantity of this kind of air, may be produced from heating a mixture of iron filings and red precipitate, or iron filings and turbith mineral.

"Five attempts were made to obtain carbonic acid gas, by exposing from half an ounce to an ounce of red precipitate, mixed with an ounce and two ounces, of the filings of bar iron, filed for the purpose, to a red heat, in a clean iron tube, without success. The mercury of the precipitate was revived, no air was obtained, and the iron was reduced to a calx.

"Mixing five drachms of the same kind of filings, and as much turbith mineral, and exposing the whole to a red heat, the same result happened.

"Having then recourse to cast iron half an

ounce of red precipitate was mixed with an ounce of the borings of cannon, and thirty-two ounce measures of air were obtained, eleven of which were fixed, and twenty-one inflammable.

"One ounce of this iron, without any red precipitate, exposed to a red heat, gave forty ounce measures of air, eight of which were fixed and thirty-two inflammable.

"One ounce of these borings, dissolved in sulphuric acid and water, left a residuum of thirty-four grains, eighteen of which were coal and sixteen siliceous earth.

"The carbonic acid gas obtained in these experiments, evidently proceeded from the coal, contained in the cast iron.

"The Doctor also obtained carbonic acid, by heating the charcoal of copper in dephlogisticated air. This charcoal of copper is made by passing the steam of alkohol over red hot copper, and as it consists principally of carbon, which is one of the component parts of alkohol, no argument can be adduced from it, in support of his hypothesis.

"He also supposes that the fixed air, procured in animal respiration, is formed without charcoal, but as we feed upon vegetable substances, which contain coal, the carbonic acid, thrown out of the lungs, must be formed of

this coal, uniting to the pure air taken into this viscus in inspiration.

"5. Of the Nitric Acid.

"It is unnecessary to refer Dr. Priestley, to the experiments of various chemists, to prove that nitric acid is composed of oxygen and azote, as he must be well acquainted with everything that has been done upon this subject.

"As the Doctor obtains this acid at pleasure, by decomposing by the electric spark, a mixture of oxygenous and hydrogenous gases, in the proportion of a little more than one measure of the former to two of the latter, he supposes that the acid is formed of these airs. But let us attend strictly, to what takes place in experiments of this kind.

"Thirty-two ounce measures of oxygenous gas, obtained from red lead and sulphuric acid, and sixty-four ounce measures of hydrogenous gas, procured from the borings of cannon and diluted sulphuric acid, both of which had been well washed in lime water, were introduced into a copper tube, and decomposed by the electric spark. About one ounce of water, remained in the tube, which after the explosion, was filled with an immense number of fine particles of matter, and which being collected upon a filter and analyzed, turned out to be copper.

"The water was of a pale blue color, and did not turn litmus paper red. Evaporated to dryness, it yielded one grain and a half of the nitrate of copper.

"This experiment was repeated with the same kind of airs, and gave the same result.

"Trying the hydrogenous gas from muriatic acid and zinc, and oxygenous gas, from red lead and sulphuric acid in the same proportions, no difference took place.

"Increasing the quantity of oxygenous gas to forty ounce measures, and reducing the hydrogenous gas to fifty-six ounce measures,and excluding the water, nitrous acid was produced.

"Repeating this experiment over distilled water, with the same quantity of oxygenous gas, obtained from red precipitate, and hydrogenous gas from malleable iron and diluted sulphuric acid, the same quantity of nitrous acid was produced, and no muriatic acid was formed, as appeared by the acid not precipitating a solution of silver in nitric acid.

"Introducing into the tube, thirty-two ounce measures of azotic gas, forty of oxygenous gas, obtained from the sulphuric acid and manganese, and twenty-four of hydrogenous gas, from malleable iron by the diluted sulphuric acid, the quantity of nitric acid did not appear to be increased.

"Repeating the experiment with sixteen ounce measures of azotic gas, fifty-six of oxygenous gas from red precipitate, and twenty-four of hydrogenous gas, from malleable iron and the diluted sulphuric acid, the greatest quantity of nitric acid was produced.

"The acid obtained in any of these experiments, was not equal to three grains of concentrated nitric acid, consequently the theory of Dr. Priestley must be wrong, for it is not probable, that fifty-six ounce measures of oxygenous gas, enter into the composition of three grains of nitric acid.

"The Doctor is certainly right when he says, if phlogisticated air be purposely introduced into the mixture of dephlogisticated and inflammable air, it will not be affected by the process. It is necessary, however, to have regard to the quality and proportion of the oxygenous and hydrogenous gases; when these airs are pure, and contain no azotic gas, which is scarcely ever the case, water only will be formed. When azotic air is mixed with them, which it almost always is, that part of the oxygen, which does not unite to the hydrogen gas and form water, joins with the azotic gas and *forms the nitric acid.*

"When carbonated hydrogen gas is used, carbonic acid, water and nitric acid will be generated.

"That inflammable air does not enter into the composition of nitric acid is evident, for none of it, nor anything into which it enters, as a constituent part, can be procured from the nitric acid, nor any combination of this acid with alkalies, earths or metals.

"On the other hand, nitric acid may be separated into its elementary parts, oxygenous and azotic gas; and if the acid was composed of pure and inflammable air, it could be made by heating red precipitate in inflammable air.

"Mr. Keir who analyzed the liquor obtained by Dr. Priestley, from the explosion of pure and inflammable air, supposed that the muriatic acid was always generated along with the nitrous.

"As no muriatic acid was obtained in my experiment, when made over distilled water, it is probable that Dr. Priestley filled his tube with pump water, containing sea salt, or that the water of his hydropneumatic tube contained some marine acid.

"I cannot conclude this dissertation, without acknowledging my obligations to Dr. Priestley, for his polite attention in shewing me a variety of experiments, when at his house in Northumberland, and for the instruction derived from reading his very valuable dissertation, on different kinds of air.

"Although I do not agree with the Doctor, in the theory which he has adopted, yet I conceive his entrance, on that branch of philosophy, denominated pneumatic chemistry, will ever be considered, as marking an era in the science."

This "last dissertation" is practically a resumé of all that Woodhouse offered at various times. It may almost be regarded as the final word on the subject of the contention. The declining years of Priestley demanded a cessation of hostilities (p. 148), and all others were abundantly satisfied on the points at issue; so the subject ceased to occupy any space in the journals of that time.

Of Priestley one writer has said: "Thus was the ingenious man effectually entangled in his errors, his ingenuity helping him to deceive himself by evading the force of truth. To err is human. If Priestley saw through a glass darkly, and but dimly discerned the truth, he at least strove, so far as in him lay, to reach the light. Posterity forgives, and may well forget, his errors in grateful recognition of the many noble services he rendered to our common humanity, and in humbling recollection of the suffering and sacrifice with which those services were requited."

To Woodhouse chemists of America owe a debt of gratitude for all that he did in order that the newer doctrine might prevail in this land. As Klaproth (p. 119) led the German scientists away from that strange entity, phlogiston, so did Woodhouse guide his contemporaries and the rising generation of American chemists into the true path. His efforts, crude when judged in the superior knowledge of the present, were however the rungs of the ladder by which chemistry mounted to its present lofty position in our Republic. The services of Woodhouse will not perish, though they may be forgotten in the great mass of chemical discoveries made since he gave himself so completely to the tasks he had assumed. His place becomes truly unique among American chemists and he will always be held in loving remembrance as a worthy pioneer in American chemistry. Now, however, the time has arrived to follow him for awhile along other lines.

In glancing through a collection of old University letters, attention was arrested by one, addressed to the Trustees, from Woodhouse, Dean of the Medical School. It bore the date, March 2, 1802, and suggested as its main purpose that the medical professors would find it agreeable, no one objecting, to examine all candidates for medical honors on the twelfth

of that month, and then came the paragraph of paramount interest in this story. It read: "Contemplating a voyage to London, to collect information relating to the Arts, and to make a collection of Fossils (minerals), I request leave of absence from the Commencement. . . . I shall return to Philadelphia, before the month of November."

This visit was fraught with much value to him. He made it a point to meet Davy and other prominent English chemists, as well as to devote a portion of his time to Paris and its savants.

With these he established most cordial relations and profited much. That he favorably impressed all with whom he came in contact, was everywhere conceded. Silliman mentions that "just before leaving London, in November, 1805, I visited again the Royal Institution under the introduction of Mr. Accum, who had formerly been assistant operator to Professor Davy. My principal object was to see that celebrated man, whom we found in his laboratory in the basement of the building (in Albemarle Street) beneath the lecture room . . .," and adds that Davy made cordial inquiry about Dr. Woodhouse, "who was here in 1802." It will be recollected that Silliman had joined the ranks of Woodhouse's students

late in 1802, and in his diary notes that Woodhouse "had just returned from London, where he had been with Davy and other prominent men. He brought with him a galvanic battery of Cruikshank's construction . . . the first I had ever seen . . . but as it contained only fifty pairs of plates, it produced little effect."

A fact of still greater moment to chemists—particularly American chemists—is that on this sojourn to Paris and London, Woodhouse took occasion to address the editor of Nicholson's *Journal:*

"PATER NOSTER ROW, May 27, 1802.

"SIR,

"I enclose for the *Philosophical Journal*, the results of various experiments, made in Philadelphia in the year 1801, upon the seeds, leaves, etc. of a variety of plants, which seem to prove, that growing vegetables, contrary to an opinion almost universally adopted, do not purify atmospherical air; and that whenever they appear to afford oxygenous gas, it is by devouring the coal of carbonic acid for food, and leaving its oxygen in the form of pure air."

Priestley and Ingenhouz had announced at various times "the property of vegetables growing in the light to correct impure air." This had been seriously doubted by Woodhouse who by a series of bold and well-devised experiments, as elaborately communicated in

the communication to Nicholson, to which reference has just been made, contends that plants in growing and seeds in germinating do not purify the air we breathe; but whenever they appear to afford oxygen, it is by devouring the coal of the carbonic acid gas for food, and leaving its oxygen in the form of pure air. He also made experiments on the effects produced by leaves of plants in air, impregnated with carbonic acid gas, and exposed to sunlight; the carbonic acid disappeared, and the "oxygenous" gas increased. "And from trials made with the fresh leaves of many different plants, exposed in sunshine in pump-water, Schuylkill water, and this latter charged with carbonic acid," he is confirmed in the same conclusion. Hence Woodhouse felt justified in denying that vegetables either decompose water, emit oxygen, or absorb azote, "as has been sometime the fashion to believe."

The Woodhouse communication is characterized by an abundance of experimental data. It must have been most convincing to all who perused it. To indicate the mode of procedure a brief quotation may find place here.

"On July 8, 1801, the day a little hazy, although the sun shone constantly, the leaves of Seriodendra tulipisiera, Cercis canadensis, Tilia Americana, Salix babylonica, Polygonium

persicarie, Phytolacca decandria, Platarius occidentalis, Allea rosea, Helianthus annus, Amygdalus persica, Conferva fontenalis, Zea maiz, Acer Glaucium were immersed in Schuylkill River water, impregnated with four quarts of the water, saturated with carbonic acid gas, from carbonate of lime and the sulphuric acid. The leaves produced in this menstruum seventy-seven drachm measures of oxygenous gas, of a very high degree of purity, whereas the leaves of the same plants, separately exposed in forty ounce measures of the water of the river alone, produced about ten drachm measures of an air, the principal part of which was azotic gas."

Even at this remote date these endeavors of Woodhouse are worthy of sympathetic study. He shows in all of them his power as an experimenter. His devotion to experimentation was contagious. His associates could not fail to imitate him, or else cease criticism because of lack of facts.

In this experimental undertaking there is every proof of Woodhouse's ability. He was a quiet but forceful leader. He possessed the originative faculty and applied it unstintedly.

Having practically silenced all opposition to the French views on combustion, on the composition and decomposition of water, he

again appears as a victorious contender in still another subtle problem which also reveals him as one very familiar with the science of botany. There is every evidence that he had been broadly trained, and brought to his several tasks a mind open, but provided with that wide knowledge which is so essential for the real investigator. Though young, compared with his foremost competitors, he was blest with unusual gifts, and best of all used them, despite the derogatory words of such men as Caldwell who said he was "phlegmatic and saturnine . . . displaying . . . the crotchets, which characterize genius." Perhaps in the last analysis the best answer to such remarks was that the success attained by Woodhouse was assured. His record remains unsullied, and in minutest details may be scrutinized with satisfaction and pride.

To digress for a moment, it is scarcely necessary to remind chemists of the intense excitement which prevailed in 1807 on the isolation of the metals, potassium and sodium, by Davy, using the Voltaic current. In this country also a profound impression was made by the discovery. It is known that efforts, with electricity as agent, were instituted to solve a number of other problems. These, however, do not belong here. The preceding facts have

been alluded to for the purpose of directing the reader's attention to the way in which these two new metals had been obtained, and to add that in the year following (1808) history reports their separation from the alkaline bases by Gay-Lussac and Thenard, on exposing these bodies to a white heat. Curaudau accomplished the same thing by substituting carbon for iron. It is remarkable that in the same year (1808) James Woodhouse observed, on exposing a half pound of soot in powder, mixed with two pounds of pearlash, in a covered crucible, to the intense heat of an iron-furnace, for two hours, that he got a mass which, when cold, was emptied upon a plate and when it was covered with a small quantity of cold water, "immediately caught fire." In the course of his remarks, relative to the behavior of the mass, he asked, "could it be due to the peculiar metal, which Professor Davy has discovered?" Again he got the metal by employing potash. Here, then, in the New World was a student liberating potassium, by an entirely novel method, for it is certain that Woodhouse was unacquainted with the discoveries of Gay-Lussac and Thenard, and that of Curaudau. Their publications could not have reached him at the time he reported his experiences. Nowhere in chemical litera-

ture is credit given Woodhouse for this discovery. Thomas Cooper who came out to America with Priestley, living with him for awhile, on one occasion wrote his son-in-law, Dr. Manners, of Philadelphia, that he knew of Woodhouse's isolation of potassium. It may be argued that Woodhouse did not realize the significance of his experiment, and did not recognize his potassium as such. If this was true at first, he did later certainly comprehend the problem in all its phases, and therefore deserves honor equally with Gay-Lussac, and Thenard, as well as with Curaudau. In fact it was his method which Brunner subsequently employed to get potassium, a method on which Robert Hare wrote rather extensively and which in many points he decidedly improved. To go further, it was the method especially applied by Berzelius and Wöhler; and was continued for years to obtain large quantities of the metal. Pains are here taken to disclose this piece of Woodhouse's work that due recognition may be accorded him. It should be a matter of pride and joy to American chemists. True, it is another instance, where the real originators of methods or discoverers are overlooked in the haste with which work is sometimes done. It is a late day to speak of all this, but there is no desire to

detract from the work of any others, it being merely desired to record Woodhouse's activities as fully, carefully and truthfully as possible.

It seems even more proper to emphasize this observation in the light of the keen interest displayed at that time by scientists throughout the world, which is quite clearly set forth in an article dated Paris, March 4, 1808. It was from the pen of Professor Frederick Hall of Vermont, who addressed it to the editor of the *Philadelphia Medical and Physical Journal*, Vol. 3, p. 7. It reads:

"I have lately received a letter from Sir Charles Blagden, formerly secretary of the Royal Society of London, in which he gives an account of an important chemical discovery, which Mr. Davy, a lecturer in the Royal Institution, has recently made. This indefatigable professor has, by means of Volta's galvanic pile, discovered the bases of potash and soda. 'He has obtained them, separately,' says Sir Charles, 'and they look like metals, both in their solid and fluid form. They also combine with metals, preserving their metallic appearance. With oxygen they recompose potash and soda.'

"The French chemists, with eagerness, caught this intelligence, repeated the necessary experiments, and found a result similar to that of

Mr. Davy. Messrs Thenard and Gay-Lussac, two of the most persevering and distinguished chemists of the age, have continued to torture these substances in a variety of ways, and have, at length, learned that they can be decomposed by a chemical process, without the aid of galvanism. The decomposition is effected by combining these alkalies with carbon and iron, by means of a very high temperature. From a combination of carbon and potash or soda, results a black mass, which suddenly inflames when placed in contact with the air, or plunged into water. The metal is obtained perfectly pure, when iron is employed instead of carbon.

"Messrs. Thenard and Gay-Lussac have already submitted the metal to a number of interesting trials, the success of which will soon be made public. Much is expected from their labours; and indeed, it is generally believed, here, that this discovery will gradually lead to others of equal, and perhaps, superior importance. As the metals of potash and soda can now be easily procured, in abundance, the relations, which they sustain to other substances, will undoubtedly be made the subject of chemical investigation.

"It is Mr. Davy's opinion, 'that all the different earths consist of bases of a peculiar

metallic nature, having a very strong affinity for oxygen, by uniting with which, they form those earths respectively.' He believes that he has already made visible, by the assistance of galvanism, the basis of the one called barytes.

"I make this communication, Sir, in hope that the subject may be sufficiently interesting to engage you, and other philosophers on your side the Atlantic, to unite your labours with those of the English and French in this new field of physical inquiry."

Having followed Woodhouse in his wrestlings with the problems presented by phlogiston; in his interesting experiences in discovering what plants do in the way of purifying air; and lastly having looked in upon his highly novel way of setting potassium free from its hydroxide, the remainder of his experiences cannot fail to attract even more strongly.

He had established himself firmly in the affections of his colleagues and students, who realized the earnestness with which he devoted himself to the problems chosen for study; and they had all confidence in the results submitted by him to the public.

Great quantities of oxygen were needed in the many experiments executed by Wood-

house. He recommended two methods for the preparation of it. Speaking of the expense attending the use of potassium chlorate as a real drawback he said, "turbith mineral, on which a solution of potash has been boiled to free it from sulphuric acid, which cannot be separated by water alone, affords oxygen gas in a state of purity equal to that derived from the oxy-muriate of potash ($KClO_3$). One ounce of oxide of mercury prepared in this way and submitted to a red heat in an iron tube, yielded forty cubic inches of oxygenous gas."

A second procedure consisted in digesting finely divided manganese peroxide with diluted sulphuric acid, "when oxygenous gas was obtained in an equal state of purity with the oxide of mercury, or the oxy-muriate of potash." These methods were given wide publicity in the home and foreign journals. Doubtless this may be explained on the basis of the excessive price of chlorate which was prohibitive. How differently chemists are now situated! The desired oxygen may be had in any amount by any one of three or four excellent methods. Indeed, something has been accomplished in the one hundred and twenty years since Woodhouse was compelled to give attention to this subject!

It has already been stated (p. 185) that upon

Woodhouse's return from England he brought with him a Cruikshank battery and that this gave him a decided distinction. Colleagues from all sections were desirous of seeing it. It also impressed his students greatly. And who can say but that a study of it, with the results from it before his eyes, was not an incentive to Robert Hare in his efforts to improve the Volta cell, and give eventually to the world his calorimotor and then the deflagrator; for after all it was under Woodhouse's supervision and guidance that Hare, and to some degree Silliman, were initiated into their scientific careers. It was said of Davy, that probably his greatest discovery was Faraday; would it be too much to assert of Woodhouse that his greatest discovery was Robert Hare?

The use of the Cruikshank battery by Woodhouse might well be expected to have led him to endeavor to inaugurate, by means of it, lines of inquiry, but there is only a single instance preserved among his papers which shows anything of this kind. It is a paper "on galvanic experiments." Some of the facts are briefly that:

"The doctor having placed a quantity of mercury in a plate, covered it to the depth of an inch, with distilled water.

"He then introduced an iron wire, connected with the copper pole, of an apparatus, formed of sixty plates of copper and zinc, four inches square, into the mercury, and immersed the other wire, applied to the zinc pole, into the water, so as to bring it as nearly as possible in contact with the mercury, without touching it.

"Immediately a constant stream of vivid and intense light, issued from the end of the wire, which could be kept up any length of time.

"It was accompanied with a hissing noise, and an oxidation of the iron.

"The light produced from wires of platina, gold, silver, copper, zinc and tin, and from the zinc and copper poles, and was visible in spermaceti oil, oil of turpentine, spirit of wine, sulphuric acid, carbonic acid gas, azotic air, nitrous gas and pure inflammable air, when placed over mercury.

"It was not greater in oxygen air, than in carbonic acid gas, and was of the colour of the electric light.

"When a piece of fine iron wire, half an inch in length, was laid upon the mercury, covered with water, and the copper pole wire was immersed in mercury, and the zinc pole wire was introduced into the water over the wire, it was repelled with great velocity, and the

whole of the mercury was violently agitated, and when any light substances were found swimming on its surface, they were dispersed in all directions.

"By means of gold wires, placed in a solution of pure caustic potash, or of the pearl ash of the shops, Woodhouse obtained five cubic inches of oxygen and hydrogen gas, of a high degree of purity, in fifteen minutes; whereas pump-water, tried under the same circumstances, for the same time, yielded but a fourth of a cubic inch of these airs, contaminated with forty per cent azotic gas.

"The agent Woodhouse used, to excite the galvanic influence, which had never been tried in Europe, was a solution of the sulphate of copper or blue vitriol. It acted in the same manner as the nitric or sulphuric acids, by giving oxygen to the zinc, but was preferable to them, as it did not produce either nitrous air or hydrogen gas.

"He considered the galvanic influence, as depending altogether upon oxygen, without which it could not be produced."

It is just possible that these observations were in consequence of a letter which Mr. W. H. Pepys, Jr., of London wrote Woodhouse in these words:

"We have been extremely interested lately,

with some galvanic experiments made by Mr. Humphrey Davy.

"The negative or the positive end of the trough of Cruickshank, has the power of completely decomposing all chemical compounds, solid or fluid.

"The method of making those on solids, is by drilling two holes in two pieces of sulphate of lime or plaister of Paris. For instance, they are placed upright, filled with distilled water and the positive gold wire is put in one, and the negative gold wire in the other: a syphon or communication is then made between the two, by a piece of fibrous gypsum or asbestos.

"In a few minutes by the test papers, an acid is found in one and an alkali in the other. The experiment being continued, gives sulphuric acid in one, and a solution of lime in the other. The acids arranging themselves on the positive side, while the alkalies and metallic oxides go to the negative.

"Metallic wire not oxidable, and pure distilled water should be used to have the effect.

"Some of the decompositions are attended with deflagrations, as the concentrated nitrate of ammoniac. Gold cones or cups, containing about eight or ten drops of solution, with an

asbestos syphon, are extremely useful for these experiments."

Association with Davy, it would be thought, would have prompted Woodhouse, on his return from England to try the exhilarating effects of nitrous oxide. Its properties could not have failed to be the subject of comment when Davy and he were together, or when Woodhouse was in the company of other chemists. It is scarcely conceivable that he could have escaped Davy's enthusiasm. "Having inhaled the gas himself to learn whether it would increase his stock of divine afflatus, Davy advised his friends, Southey and Coleridge that he walked amidst the scenery of the Avon, rendered exquisitely beautiful by bright moonshine and with a mind, filled with pleasurable feelings, breathed the gas and indited the following effusion:

"Not in the ideal dreams of wild desire
Have I beheld a rapture-awakening form;
My bosom burns with no unhallowed fire,
Yet is my cheek with my blushes warm,
Yet are my eyes with sparkling lustre filled;
Yet is my mouth replete with murmuring sound;
Yet are my limbs with inward transport filled,
And clad with new-born brightness around."

"Whether Davy ever again essayed to tempt the Muse when under the influence of nitrous oxide is doubtful."

Silliman narrates that "Woodhouse attempted to exhibit the exciting effects of Davy's nitrous oxide, but failed for want of a sufficient quantity of gas, and the tubes were too narrow for comfortable respiration." He then proceeds to recount: "An amusing occurrence which happened one day in the laboratory. Hydrogen gas was the subject, and its relation to life. It was stated that an animal confined in it would die; and a living hen was, for the experiment, immersed in the hydrogen gas, with which a bell-glass was filled. The hen gasped, kicked, and lay still. 'There, gentlemen,' said Woodhouse, 'you see she is dead;' but no sooner had the words passed from his lips, than the hen with a struggle overturned the bell-glass, and with a loud scream flew across the room, flapping the heads of the students with her wings, while they were convulsed with laughter."

From Woodhouse himself, relative to the effects of nitrous oxide, came this printed statement:

"In the year 1802, I prepared a large quantity of the nitrous oxide or dephlogisticated air, from the nitrate of ammoniac, made by decom-

posing nitre, by the sulphate of ammoniac, and by adding the nitric acid to sal ammoniac.

"A great number of gentlemen, belonging to my chemical class, who intended to breathe the gas, were present in the morning, when I was filling my air-holders with it, and saw all the operations going forward.

"In the afternoon, being alone at my laboratory, at two o'clock the air was examined, and found to be extremely impure, having made use of too great a degree of heat in generating it.

"Expecting the gentlemen at three o'clock, the impure air was thrown away, and the air holders filled with atmospheric air.

"This air was breathed by a variety of persons, under the impression that it was nitrous oxide, and the greater part of them were affected by quickness of pulse, dizziness, vertigo, tinnitus aurium, difficulty of breathing, anxiety about the breast, &c."

"The following is a letter received from one of the gentlemen:

"'The nitrous oxide produced no sensible effect, for perhaps the space of a minute after I began to respire it. Soon after I was affected with a tinnitus aurium, which affected the sense of hearing, in the same manner as water, in a state immediately preceding ebullition

does. At the same time I had a sensation similar to that produced by swinging; afterwards a difficulty of breathing gradually came on, which at length necessitated me to discontinue the respiration of the air. The difficulty of breathing and the tinnitus then soon subsided, but the peculiar sensation in my breast, continued sometime longer, which was succeeded by slight nausea, which continued six or eight hours.'

"A short account of the effects of the atmospheric air was sent to Dr. Mitchill of New York, who published it in the fifth volume of the *Medical Repository*.

"For many years after this, not finding the experiments of Mr. Humphrey Davy on this subject, confirmed by other chemists, I believed that the influence of the imagination, caused all the effects ascribed to the nitrous oxide.

"In the winter of 1806, having prepared a quantity of this gas, extremely pure, from the nitrate of ammoniac, made by a direct combination of the nitric acid and the carbonate of ammoniac; two quarts of it were administered to Mr. Henry Latrobe, fourteen years of age, who breathed it in a very fair manner. In a minute he was most violently affected. He walked up and down the laboratory with

a quick step, elevating his legs, then suddenly throwing them down on the earth. He rubbed his hands rapidly over each other, and laughed immoderately and convulsively. The tears rolled down his cheeks in large drops, and he frothed at the mouth.

"Witnessing these effects, and knowing the impossibility of counterfeiting such symptoms, I immediately resolved to try the effects of the gas on other persons.

"Doses of two and four quarts were always administered.

"Mr. J. D. McClean upon breathing the gas, fainted and recovered in about three minutes.

"Mr. George Thornton looked wild, jumped over a high railing, and the effect suddenly ceased.

"Mr. Martin raised his hands over his head and jumped about the room.

"Mr. Pope placed his arms a-kimbo, and surveyed the audience with great contempt.

"Mr. William Barton was very much deranged. He ran about the laboratory, bellowed like a mad bull, and struck at every person near him. A week after, the gas being administered to him a second time, produced the same effect. He felt an increase of strength, after recovering from the effects of the air.

It was with great difficulty that I could remove the mouth piece of the bladder from his mouth.

"Mr. N. S. Allison fainted, but recovered in a few minutes. Upon breathing the air seven days afterward the same effect was produced.

"Mr. Thomas Prioleau exclaimed, 'I am in heaven, ye gods, stars, comets, meteors, Mohamet's jackass, the Elysian fields are hell compared with this,' and then fainted.

"Mr. Robert Patterson was affected with violent laughter.

"Mr. Samuel Jackson in the same manner.

"Mr. Peter Curtis laughed very heartily.

"A week after, having a large air holder, filled with atmospheric air, standing along side of two others containing nitrous oxide, the atmospheric air was given to him, but it produced no effect.

"Mr. Gerard Snowden fainted, but soon recovered.

"Mr. William Handy laughed and fainted.

"Mr. William Tyler fainted and recovered in four minutes. Seven days after, breathing the air a second time, the same effect was produced.

"Mr. Cornelius Dupont laughed and fainted.

"Baron John de Bretton experienced pleasurable sensations.

"Mr. Benjamin Kugler laughed; upon giving

him atmospheric air a week afterwards, he was not affected.

"Mr. Thomas Lewis was much enraged. He caught me by the collar, pulled at my cravat, tore my coat, ran about the room and struck at every person near him.

"Mr. Evans breathed atmospheric air; it produced no effect.

"Mr. Wheaton after taking four quarts of the nitrous oxide into his lungs, was beginning to be affected; he cried out in a very rapid manner, 'Give me another bottle, give me another bottle.'

"The gas was tried upon fifteen other persons, without producing any effect. Some of them breathed it in a very fair manner; others were much frightened, and mixed it with the air of the atmosphere.

"I am not perfectly convinced, that the gas produces all the effects ascribed to it, by the justly celebrated Mr. Humphrey Davy, who first took it into his lungs; and I am happy in having this opportunity, of confirming his experiments."

It may not be out of place to include here an experience with this gas, transmitted by an early student of the old Philadelphia laboratory, after administering it to a young man, just taking up chemical studies: "He was a tall,

handsome youth, with gentle manners, and was a general favorite. He inhaled the gas freely, and then with the greatest gentleness and affection of manner imaginable, put his arms around my neck and placed his cheek to mine, first one side and then the other; when I remarked that such evidence of affectionate regard was a full compensation for the pugnacious treatment I had before received, and, by the time I had entirely finished my sentence, he left *me* and embraced the stove-pipe with equal affection!"

And another wrote: "One of our gravest citizens, a man of thirty-eight or forty years of age, was made to caper about like a monkey, with all the extravagant gestures of a tragedian, and the grimaces of a harlequin. Some effect was produced upon all that breathed the gas, and the full effect was manifested in six instances out of eight. One of these took place before many spectators, and was so marked as to banish every doubt."

At present, students of chemistry do not include the inhalation of this gas among their laboratory experiences! They are more apt to hear of it as an anesthetic, quite benign in its effects and preferred in numerous operations by surgeons. The gas, as known to everyone, constituted one of Priestley's distinguished

discoveries, and as observed, Woodhouse meets him again on his own ground; but in the delightful words of T. E. Thorpe:

"If by some evil chance the cold and damp of this coming winter should drive some of you to the dentist, and if after seating you in that awful chair and harrowing your distracted nerves with the sight of his murderous tools, he humanely offers to send you to sleep with his nitrous oxide, by all means let him, and, when you wake with the sweet consciousness that 'it is all over,' give a passing benediction to the memory of Priestley, for he first told us of the existence of that gas."

Reviewing the publications of Woodhouse, other than those pertaining to his experimental investigations, these present themselves:

1. The *Young Chemist's Pocket Companion* (1797), to which ample reference has been made (p. 77).

2. *Parkinson's Chemical Pocket Book* (1802), which is a revision of the London second edition (1801). It is a striking volume, with a great mass of facts concisely set forth, and contains "a delineation and account of another chemical apparatus invented by Woodhouse. The maker of experiments will find this to be simple, cheap

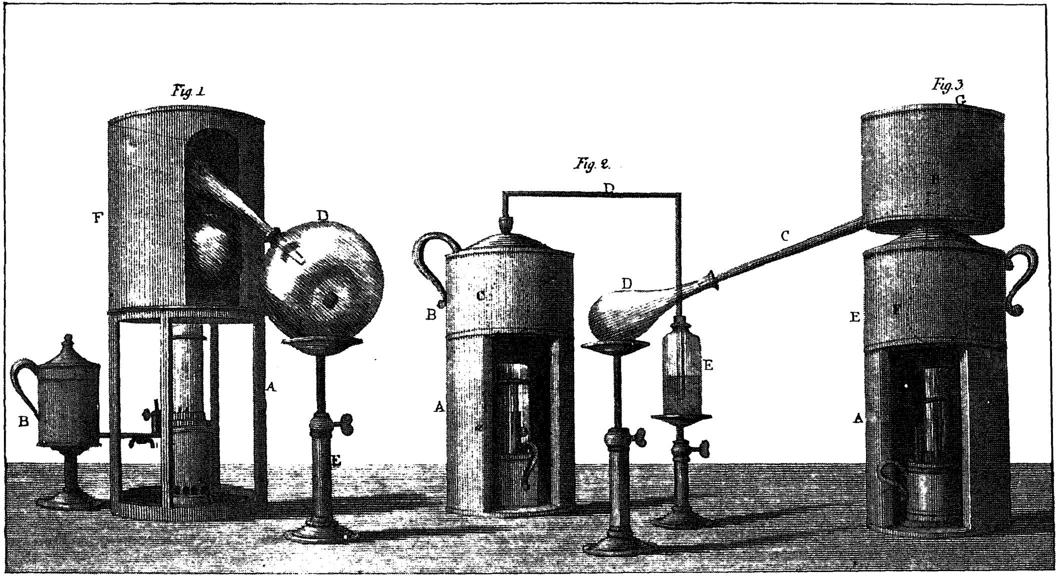
and applicable to a great variety of processes." As this apparatus, termed the "Economical Laboratory" or "Economical Apparatus" of Woodhouse, is pictured in very many of the books devoted to chemistry, which appeared shortly after 1800, it is here reproduced. Its construction and uses will be quite readily understood from the following paragraphs:

PLATE 1

"Fig. 1. A is a stand, made of tin, thirteen inches high, consisting of a flat bottom, from which proceeds four upright pieces, of the same metal, one inch broad, which are riveted to the top, in which there is a round aperture, three inches in diameter, to receive the bottom of a retort or oil flask. B is one of Argand's lamps; C, a retort, luted to a receiver D, which is supported by a frame of wood E. The case F, which is placed over the retort, to confine the heat of the lamp, is formed of two pieces of tin which include a column of atmospheric air one inch thick between them. It is ten inches in height; the opening in the side is three and a half inches, and the internal diameter is seven inches.

"Fig. 2. A is a cylindrical vessel of tin, thirteen inches high, and twenty-one in circumference, open at A, so as to admit a lamp,

PLATE I



Economical Apparatus of James Woodhouse, M.D.
Professor of Chemistry, in the University of Pennsylvania, &c.

with a round aperture in the top, three inches in diameter. B is a circular case, four inches high, formed of two pieces of the same metal, which include a column of atmospheric air, one inch thick, at the top and on the sides.

"The lower part has an opening five inches in diameter, and in the middle of the upper part, there is an aperture, to receive the neck of an oil flask. C is a flask, from which proceeds the tube D, which enters the bottle E.

"In using this apparatus, the flask, containing the subject of the operation, must be placed on the cylindrical body A. The case B is then to be put over the flask, and the tube D, which enters a perforated cork, luted to it with a strip of paper, covered with a paste, made of flour and water. The atmospheric air which B contains, is a bad conductor of heat, hence upon applying an Argand lamp to the bottom of the flask, the heat is accumulated round its sides, and thus prevented from flying off, into the air.

"Fig. 3. A is a cylindrical vessel of tin, E the case containing the atmospheric air, and F an oil flask, on the neck of which, the head of an alembic B, made of tin or copper, seven inches high, is placed. C, the neck of this vessel, thirteen inches long, enters an oil flask D.

"To use this apparatus, the flask must be placed on the top of the cylindrical body A. The vessel containing the atmospheric air, is then to be placed over the flask, and the head of the alembic fixed to its neck. G, the part over the top of the head of the alembic, may be filled with cold water.

"This economical apparatus may be used:

"First. In obtaining gases from certain substances, which require the application of heat; as oxygenous air, from manganese or red lead and the sulphuric acid; or ammoniacal gas, from lime and sal ammoniac; or oxygenated muriatic gas from manganese and the marine acid, &c.

"Secondly. In making ammoniac, and the liquid and concrete carbonate of ammoniac; in uniting sulphur with potash, soda and lime; to compose sulphuret of potash, soda and lime; to form fulminating mercury, silver and gold, and the prussiates of lime, potash, &c.

"Thirdly. In procuring several of the acids, as the nitric, muriatic, oxy-muriatic, oxalic, fluoric, acetic, &c.

"Fourthly. In distilling water, and spirituous liquors to form alcohol &c., and uniting the sulphuric acid and alcohol, to make ether, &c.

"Fifthly. In the drying of powders, and in evaporating water, and some of the acids from

saline solutions. A vessel of tin, copper, or glass, or a queens-ware saucer, may be placed on the top of either of the stands, for this purpose.

"Sixthly. In making experiments upon all kinds of dyeing, drugs, and

"Seventhly. In analyzing earths and the ores of metals, in the humid way.

"This apparatus is preferable to that of Guyton in many respects.

"First. It is less expensive. The lamp of Guyton, is one of the worst of the kind for a Chemical Laboratory. There is no occasion for a number of screws, to elevate or depress the retort or lamp, for a great or low heat may be made, merely by raising or lowering the wick.

"Secondly. It would be no very easy matter, to place an oil flask on the ring of Guyton's apparatus, so as to connect a long tube with it, to obtain oxygenated muriatic acid gas, ammonical gas, &c. And in the winter season, the cold air, acting on the belly of the vessel placed there, would deprive it of a portion of heat, and if the ore of a metal was boiled with an acid, in an oil flask, it would keep jumping from the ring.

"When the case lined with coal is placed over a flask, the heat is accumulated round it, and the vessel is kept steady in one position.

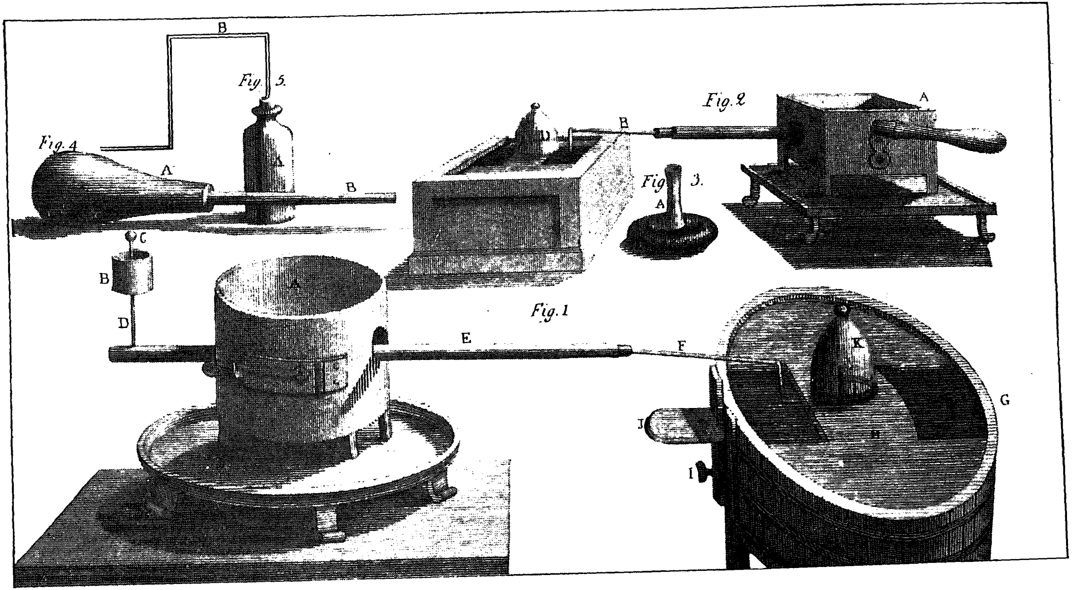
Retorts are also procured with difficulty, at this time, even in the great cities of the United States. It is of great consequence then to procure a substitute for them. The head of the copper or tin alembic, Fig. 3, fixed on an oil flask, and its neck communicating with another, form a distilling apparatus, which may be used, in a great many chemical operations.

"These observations are the result of experience.

Plate 2

"Fig. 1. The furnace A is formed of thick sheet iron, is ten inches high from the grate, and ten inches in diameter. There are two holes in its sides, to admit an earthen, iron or copper tube, and a door on one side to put in fuel, when a still, or any other piece of apparatus is placed on its top. B is a brass funnel, and C a wire of the same metal, which enters into the tube of the funnel D, which is screwed to the gun-barrel E. F is a bent tube made of glass, tin or copper, which is fixed in the mouth of the gun-barrel, and which enters under the shelf H, of the hydropneumatic tub G, which should be made of cedar, and the size of a common washing tub, but of an oval form. I is a thumb screw, to fix another shelf J to the tub. K is a bell-glass.

PLATE II



DR. WOODHOUSE'S ECONOMICAL APPARATUS

"If water or any other fluid is put in the funnel B, it may, by turning the wire, be made to pass drop by drop, over any substance, confined in the gun-barrel, and the aerial product will be received in the bell glass K.

"Fig. 2. A is a chafing dish, a few inches larger than the common size, containing a gun-barrel cut in two parts, and closed at one end by welding. B, a bent tube, which enters under the shelf of the hydropneumatic box C. D, a bell glass.

"Fig. 3. A is a subliming vessel, shaped flat like a turnip, and having a projecting neck, two or three inches in length, with an aperture in it, about an inch in diameter.

"Fig. 4. A is a cast iron matrass, sixteen inches in circumference, and about a foot long, into the mouth of which the gun-barrel B is well ground, for making oxygen gas, carbonated hydrogen gas, oxyd of carbon, &c.

"Fig. 5. A is an eight ounce vial, into the mouth of which the bent tube B enters, for making hydrogen gas, nitrous air, carbonic acid gas, &c."

3. Parke's *Chymical Catechism* was revised in 1807 by Woodhouse. It "is embellished with a frontispiece of his Economical Laboratory." It is really a very attractive book.

"The object of this publication," said *Nicholson's Magazine*, "is to unfold the Science of Chymistry to Artizans and Young People by way of question and answer." It contains an address to parents in which chemistry is portrayed as never occurs in these modern days. For example:

"As some persons may not be apprised of the value of chymical knowledge, it may be necessary to enumerate a few of the advantages which arise from its acquisition; for, in order to induce that general attention to the science which it deserves, its *utility* must be demonstrated:

"It would be no difficult matter to show that the world might derive great advantages even from the diffusion of a theoretical knowledge of philosophy and chymistry. An instance or two will place this assertion in a clear point of view. Two thousand years ago, Archimedes was ridiculed for his attention to mathematics and the abstruse sciences; yet, owing to this knowledge, he was enabled to invent such mechanical engines as were sufficient to resist the whole Roman army. And such a dread had the soldiers of this man's knowledge, that if a rope only were hung down the walls of the city of Syracuse, the whole army would retire from before it in the utmost consternation.

"A further proof of the importance of the dissemination of chymical knowledge may be taken from the construction of the Steam Engine; Mr. Watt having often acknowledged that his first ideas on this subject were acquired by his attendance on Dr. Black's Chymical Lectures, and from the consideration of his theory of latent heat and the expansibility of steam.

"The well informed people of France are so satisfied of the importance of chymical knowledge, that chymistry is already become an essential part of education in their public schools. . . . The science that we are recommending to your regards, has for its objects every substance of the material world, and is therefore equally interesting to every civilized nation upon earth.

"Is your son born to opulence,—is he the heir to an extensive domain; make him an analytical chymist, and you enable him to appreciate the real value of his estate, and to turn every acre of it to the best account. Has he a barren tract of country, which has been unproductive from generation to generation, he will explore its bowels with avidity for hidden treasures, and will probably not explore it in vain. By analyzing the minerals which he discovers, he will ascertain with facility and

exactness what proportion of metal they contain, and which of them may be worked to profit. Thus he will operate on sure grounds, and will be prevented from engaging in expensive and unprofitable undertakings.

"Chymistry will teach him also how to improve the cultivated parts of his estate; and, by transporting and transposing the different soils, how each may be rendered more productive. The analysis of the soils will be followed by that of the waters which rise upon, or flow through, them; by which means he will discover which are proper for irrigation; a practice, the value of which is sufficiently known to every good agriculturist.

"Will he occupy his own estate, and become the cultivator of his own land; he must of necessity be a chymist, before he can be an economical farmer. It will be his concern not only to analyze the soils on the different parts of his farm, but the peat, the marl, the lime, and the other manures must be subjected to experiment, before he can avail himself of the advantages which might be derived from them, or before he can be certain of producing any particular effect. The necessity of analysis to the farmer is evident, from a knowledge of the circumstance, that some kind of lime is injurious to land, and would

render land hitherto fertile actually sterile. Besides, a knowledge of the first principles of chymistry will teach him when to use lime hot from the kiln, and when slacked; how to promote the putrefactive process in his composts, and at what period to check it, so as to prevent the fertilizing particles becoming effete, and of little value. It will teach him moreover the difference in the properties of marl, lime, peat, dung, mud, ashes, alkaline salt, soap waste, sea water, etc., etc., and, consequently, which are most suitable for the different kinds of land. A knowledge of the chymical properties of bodies will thus give a new character to the agriculturist, and render his employment rational and respectable.

"Are you a Practitioner of Medicine, and have acquired great and deserved reputation in your profession,—if you are not a chymist, you must recollect many painful disappointments, and must have witnessed very unexpected results from the effects of medicine, when you have administered two or more powerful remedies in conjunction. A slight knowledge of chymistry would have informed you, that many of the formulæ in the Pharmacopeia, which are salutary and efficacious, are rendered totally otherwise, if given with certain other medicines,—not to say often

destructive. Many instances of these chymical changes might be adduced, but one will suffice. Mercury and oxymuriatic acid have both been administered by medical men, and, separately, either of them may be taken without any injury to the animal economy; but if a physician, ignorant of the chymical operation of bodies on each other, should give these substances in conjunction, the most dreadful consequences might ensue, as oxymuriate of mercury is a most corrosive poison.

"Does your son wish to follow your profession, charge him, when he walks the hospitals, to pay particular attention to the Lectures on Chymistry, and to make himself master of the chymical affinities which subsist between the various articles of the Materia Medica. This will inspire him with professional confidence; and he will be as sure of producing any particular chymical effect upon his patient as he would if he were operating in his own laboratory. Besides, the human body is itself a laboratory, in which, by the varied functions of secretion, absorption, etc., composition, and decomposition, are perpetually going on; how, therefore, could he expect to understand the animal economy, if he were unacquainted with the effects which certain causes chymically produce? Every inspiration we take, and

every pulse that vibrates within us, effects a chymical change upon the animal fluids, the nature of which requires the acuteness of a profound chymist to perceive and understand. Neither can a physician comprehend the nature of the animal, vegetable, or mineral poisons, without the aid of chymistry. Many thousand lives have been lost by poison, which might have been saved if the physician had been in possession of the knowledge which he may now acquire by a cultivation of chymical science. And, though the operation of many of the poisons upon the system be in these days well understood, nothing but a knowledge of chymistry can enable the practitioner to administer such medicines as will counteract their baneful effects.

"If we look to the Manufactures . . . there is scarcely one of any consequence that does not depend upon chymistry, for its establishment, its improvement, or for its successful and beneficial practice. In order to see the connection which subsists between chymistry and the arts, it will be necessary to take a short view of the principal trades.

"One of the staple trades . . . is the manufacture of iron; and it will be found, that from the smelting of the ore to the conversion of it into steel, every operation is the effect of

chymical affinities. In the first place, it requires no small share of chymical knowledge to be able to appreciate the value of the different ores, or to erect furnaces for their reduction, which shall be contrived in the best possible manner for facilitating their fusion, and for producing good pigs. The subsequent processes to convert it into malleable iron, are entirely chymical, and will be conducted to the best advantage only by those who have acquired a knowledge of the chymical changes which take place in these operations. The making of cast steel, which has been kept so profound a secret, is now found to be a simple chymical process, and consists merely in imparting to the metal a portion of carbon, by means of fusing it in crucibles with carbonate of lime.

"The manufacturers of utensils, etc., in cast iron (called iron founders) will also acquire some valuable information by the study of chymistry; as it will teach them how to mix the different kinds of metals; how to apportion the carbonaceous and calcareous matter; and how to reduce the old metal, which they often receive in exchange; many hundred tons of which are annually sent away as ballast for ships, for want of that knowledge, which would enable them to convert it into good salable iron.

"The woollen, the cotton, and the calico manufactures are also become of great importance. . . . In order to preserve these sources of national wealth, the utmost attention must be paid to the beauty, the variety, and the durability of their several colours. Now of all the arts, none are more dependent upon chymistry than those of dyeing and calico printing. Every process is chymical; and not a colour can be imparted, but in consequence of the affinity which subsists between the cloth and the dye, or the dye and the mordant which is employed as a bond of union between them. It is surely then evident how valuable a chymical education must be to that youth who is designed for either of these trades, and how necessary is that portion of knowledge which shall enable him in a scientific manner to analyse his different materials and to determine the kind and the quantity necessary for each process. After all, his colours will be liable to vary, if he do not take into the account, and calculate upon, the changes which take place in them by the absorption of oxygen. A knowledge of which, and of the different degrees of oxidizement, which the several dyes undergo, requires no small share of chymical skill; and yet this skill is absolutely necessary, to enable either the dyer or the calico

printer to produce in all cases permanent colours of the shade which he intends. Moreover, these artists must be indebted to chymistry for any valuable knowledge which they may acquire of the nature of the articles they use in their several processes; not to say that they are wholly dependent upon this science, for the artificial production of their most valuable mordants, and for some of their most beautiful and brilliant colours.

"The art of bleaching, which is so intimately connected with calico printing, has also received such great improvement from the science of chymistry, that no man is now capable of conducting it to the best advantage without a knowledge of the principles on which the present practice is established.

"The manufactures of earthen wares and porcelain, which were so much improved and extended by the industrious and ingenious Wedgwood, and give employment to thousands of the community, are dependent upon chymistry for the successful management of all their branches, from the mixture of the materials which form the body of the ware, to the production of those brilliant colours which give a value to the manufactures by their permanency and beauty.

"Mr. Wedgwood was so sensible of the

importance of chymistry to these arts, that he not only applied to the study of the science himself, but upon the death of the celebrated Dr. Lewis . . . he actually engaged his assistant, a Mr. Chisolme, to experimentalize with him, and to devote his whole time to the improvement of the manufacture by the application of his chymical knowledge, of which perhaps few men at that time had a larger share. A faint idea of the advantages which he derived from these sources may be conceived from the following circumstance. Dr. Bancroft in his Philosophy of permanent colours, when treating iron, says, 'I remember having been told, by Mr. Wedgwood, that nearly all the fine diversified colours applied to his pottery were produced only by the oxides of this single metal.' This one fact is sufficient to show with what assiduous application he must have studied chymical science, and how insufficient every attempt to bring his manufacture to the perfection which it has now attained, would have been, without this attention.

"The sister art of making glass is also entirely chymical, consisting in the fusion of silicious earth with the oxides of lead and alkali. In this trade, as well as in many others, the chymical manufacturer, and the man of enlightened experience, will have many advantages.

He will not only know how to analyse his alkalies and to ascertain their exact value before he purchases, but he will be enabled, on chymical principles, to ascertain the exact quantity necessary for any fixed portion of silex, which with others must always in the first instances be a matter of uncertainty, and must repeatedly subject them to losses and disappointment.

"The tanning of hides is a process which was formerly carried on by persons who merely followed a routine of operations to which they had been accustomed without knowing the real cause of any of the changes produced on these substances. This art, which consists in impregnating the animal matter with a peculiar principle taken from the vegetable kingdom, which enables it to resist moisture, and gives it great strength and firmness, has been well explained by Mr. Sequin. According to him, the gallic acid of the bark deoxidizes the skin, and as the skin loses its oxygen the tan combines with it, and forms it into leather. It is now known, that many substances, besides oak bark, contain tan, and to modern chymistry we are indebted for the means of discovering with accuracy the quantity of tan which the several astringent vegetables contain. The arts will owe a further obligation to this science

whenever it shall lead the way to the discovery of a cheap substitute for oak bark. At present the demand is so great that it is not only imported from the continent, but trees are cut down in this country on purpose for the bark, which are of no other use whatever. Should the chymical tanner not be fortunate enough to make a discovery of the kind just mentioned, he will at least be able to analyse the substances now in use, and to appreciate their relative value; a matter of no small moment to a man who operates upon a large scale.

"The manufacture of soap, a trade of considerable importance, . . . has in general been conducted, like many of the foregoing, without any regard to system; and yet, perhaps, there is no art which may be benefitted in such various ways by chymistry as this. To those who are designed for this trade I have no hesitation in recommending the study of the science as a matter of the first importance. Many thousands per annum, which are now lost to the community, would be saved, if the trade was in general carried on upon scientific principles. Make a soap boiler a good chymist, and you teach him how to analyse barilla, kelp, potash, etc., so as to ascertain the proportion of alkali in each, and which is the most advantageous for him to purchase; a matter of

mere guess with the common manufacturer. When these articles are at an exorbitant price, he will have recourse to various residuums, which he will decompose by chymical means, and make use of as substitutes. He will learn, in choosing his tallows, how to avoid those which contain a large proportion of sebacic acid, which require much more barilla than good tallow, and yet produce less soap. He will know how to oxidize the common oils and oil dregs, so as to give them consistence, and render them good substitutes for tallow. He will know how to apportion his lime so as to make his alkali perfectly caustic, without using an unnecessary quantity of that article. He will be aware of the advantage which may be derived from oxygenating the soap while boiling; a knowledge of the chymical affinities will teach him how, at a cheap rate, to make as good and as firm a soap with potash, as with the mineral alkali; and how to take up the heterogeneous salts so as to give the alkali full opportunity of forming a chymical combination with the oils, tallows, etc. And lastly, he will know how to make use of the waste lies so as to decompose the salts which they contain, and convert them to good and serviceable alkali, to be used in future operations.

. . . . .

"The brewing of fermented liquors, which is a trade of considerable consequence . . . is a chymical process altogether. To those persons, whose concerns are so large that it would require a princely fortune to purchase even the utensils, it must surely be of the utmost importance to acquire some knowledge of the principles of bodies, and of the nature of those changes which take place in the materials upon which they operate. I would therefore say to such persons, Give your sons a chymical education, and you will fit them for conducting, in the best possible manner, the business which you have established. Hence, they will learn how the barley, in the first instance, is converted to a saccharine substance by malting; how the fermentative process converts the saccharine to a spirituous substance; and how the latter, by a continuation of the process, becomes changed into vinegar. The nature of fermentation (which till lately was entirely unknown) will be studied and understood; and they will not only have learnt the means of promoting and encouraging this process, but how to retard and check it, whenever it is likely to be carried too far; so that the scientifick brewer will be as sure of uniformly obtaining satisfactory results, as he would if he were

operating on matter by mere mechanical means.

. . . . .

"The refining of sugar is also a chymical process; every branch of which depends upon laws well known to chymists. The separation of the sugar from the molasses; the absorption of the superabundant acid; the granulation of the purified sugar; and the chrystallization of candy; will all be conducted most economically, and with the least difficulty, by those who have studied the science with a view to the improvement of their art.

. . . . .

"It has been objected to the teaching of chymistry to youth, that it is a science difficult to acquire; and that the terms are an insuperable bar to its early attainment; but I am of opinion, that the elements of chymical knowledge may be taught much earlier than is imagined by many who never made the attempt; and that, instead of any difficulty arising from the technical language of the science, the preceptor will find the new nomenclature a considerable auxiliary, greatly facilitating the communication and reception of its general doctrines.

. . . . .

"Moreover, it is the necessary consequence

of an attention to this science, that it gives the habit of investigation, and lays the foundation of an ardent and inquiring mind. If a youth has been taught to receive nothing as true, but what is the result of experiment, he will be in little danger of ever being led away by the insidious arts of sophistry, or of having his mind bewildered by fanaticism or superstition. The knowledge of facts is what he has been taught to esteem, and no reasoning, however, specious, will ever induce him to receive as true what appears incongruous, or cannot be recommended by demonstration or analogy."

The entire article would delight the enthusiasts of the science. One wonders how those early champions of the usefulness of chemistry would regard the evidences of its powers as exhibited in the warring countries of 1914–18.

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4. Chaptal's *Elements of Chemistry* (1807). This was a work written by a former Minister of the Interior in France. It was a famous book. Four American editions were printed, the last by "the learned and indefatigable professor of chemistry in Pennsylvania, who added numerous notes, containing information not embraced by the original." The additions

were, indeed, "great and improved." Present day students of chemistry would profit very much if they were to examine these two volumes with care. The evidence of Woodhouse's wide range of knowledge is seen in his voluminous footnotes. The time consumed in reading these volumes would not be lost. Just as a matter of curiosity it may be here said that in Volume I, p. 218, mention is made of *agustina*, "an earth found in the Beryl of Saxony, and is so called, because it has the property of forming salts, which are nearly destitute of taste." Is this to be in contradiction to beryl or glucina, indicating sweet, a property of its salts? According to Tromsdorff the properties of agustina are:

"1. It is white and insipid, and when pure resembles alumine.

"2. It combines with acids, and forms with them salts, which have little or no taste.

"3. It does not combine either in the humid or dry way, with alkalies or their carbonates.

"4. It retains carbonic acid but feebly; and

"5. It is insoluble in water."

Agustina constitutes another of the long line of defunct elements.

Woodhouse's edition will always be of value

to the student of chemical history. Without question he expended his very best powers in its production, and hence it was justly prized in chemical circles of the first decade of the nineteenth century.

Among Woodhouse's contributions to American mineralogy was one on "a very curious ore of titanium one of the newly discovered metals." It had been found in New Jersey. A rather large specimen of it had found its way to Dr. Mitchill of Columbia University, who in turn passed it to Woodhouse for analysis. At first it was thought to be a zinc ore. Bruce, the able American mineralogist was not so minded. His views were shared by European correspondents. "Their united opinion was that it is chiefly the oxide of titanium combined with that other form of the metal which, from its having been found in the valley of Menachan, in Cornwall, England, has been called Menachanite." Accordingly, Woodhouse engaged in its analysis, reporting the results to his friend Mitchill in these words:

"The specific gravity of this metal is 5.28. When viewed, it has the appearance of black spots, the size of duck shot, surrounded by a red substance; and streaks of a white powder,

which is lithomarge, are dispersed through it. Upon looking at it through a microscope, a crystal of titanium was seen adhering to it. One hundred grains of it, reduced to an impalpable powder, and exposed one hour to the intense heat of an air-furnace, lost fifteen grains in weight, and from a brown, was turned of a black colour.

"One hundred grains of it, submitted to heat in the same manner with charcoal, produced a great number of small globules of pure iron. This metal can be separated from the powder by a magnet.

"One hundred grains of it, boiled in aqua regia, was totally soluble in this agent, which proves it contains no silex.

"The Prussiate of potash, added to this solution, yielded a blue precipitate, which, when dried, weighed three hundred grains. Now if we divide this sum by six, we shall have the quantity of metallic iron in the hundred grains of the ore, which is fifty.

"A portion of lime was thrown down from a solution of the mineral, in aqua regia, by the oxalate of potash. Carbonate of ammoniac, and a solution of pot-ash, produced a copious white and gelatinous precipitate.

"One hundred grains of it were mixed with six hundred of pot-ash, and submitted to

intense heat one hour, in a black lead crucible. The part remaining in the crucible was powdered, boiled in water, and filtered. Upon adding a small portion of muriatic acid to the water, a white precipitate was thrown down, which was supposed to be the titanium. Upon collecting it, and mixing it with a small portion of spermaceti oil and charcoal, it was exposed to the heat of a blacksmith's forge, when nothing was obtained but a shiny heavy black substance, of the appearance of glass.

"When the muriatic acid was added in excess to the filtered water obtained, by boiling the residue, which remained in the crucible, in water, no precipitate was produced, until a solution of pot-ash was added to neutralize the acid.

"The solution of the mineral in nitric acid is astringent to the taste.

"The ore appears to be composed of iron, titanium, lime, alumine, and no silicious earth.

"I wish you to inform me in what part of New Jersey I can procure some of the mineral. Have you any to spare of the specimen in your possession? for I wish to continue the experiments upon it."

This analysis is a real curiosity. At present it would not pass muster. Those who have analyzed titaniferous ores will fail to perceive

in it the course they would pursue in arriving at the composition of this well-known substance. The fact that iron appears to have been regularly determined in those days, first by precipitation as ferrocyanide and this then decomposed with alkali is worthy of thought. As late as 1822, this method found preference in Buff's Quantitative Analysis. It was considered the best procedure for the separation of iron from aluminium and magnesium. The study of the gradual development of analytical methods should receive consideration from the student of chemistry. There is in it an educational evolution deserving attention.

Shortly after concluding the preceding study, Woodhouse wrote to the editor of the *Medical Museum* that a Mr. Rutland of Philadelphia had put into his hands, "a specimen of a black coloured mineral . . . found in the County of Northampton . . . about thirty miles from Bethlehem, in the neighborhood of the Lehigh, and informed me that it might be easily procured, in great quantities, at that place." This ore was in reality, as will be seen, the mineral pyrolusite. In massive form it is almost impossible to distinguish it from psilomelane, an allied substance which occurs in the same locality. Nearly one hundred years later the crystallized mineral, in unmistakeable form,

was reported from the adjacent county of Lehigh.

But not to overlook Woodhouse's observation, his language may be inserted at this place.

"Having subjected this substance to a variety of experiments, it was discovered to be Manganese of the first quality, containing little extraneous matter; and far superior to most of that which is sold in the shops of the druggists, considerable quantities of which I have frequently been obliged to throw away after purchasing it, from the impurity of the material.

"The oxygen air obtained from this native ore, was equal in purity to that which was afforded by a specimen of the foreign, sent to me by the late Dr. Priestley, the discoverer of this gas, who informed me, that it yielded an air as pure as any he had ever procured during the course of his life.

"Manganese is useful to the physician, in consequence of the air it affords, and to which some of the most violent diseases to which the human body is subject, have given way; to the bleacher, paper maker, and manufacturer of glass, as a destroyer of colouring matter, when combined with the marine acid; to the potter, as giving a black colour, and assisting in glazing his earthen ware; and to the philosopher and artist, as containing a gas, which,

combined with certain combustible bodies, will generate a degree of heat unattainable by other means.

"As the science of mineralogy is little attended to in the United States, the intention of this communication is, to induce gentlemen residing in the country, to pay some attention to the mineral productions of their fields, by which means they may greatly profit themselves, and render the most important services to the arts, yet in their infancy in this part of the world.

"Any person desirous of information, concerning any of our native fossils (minerals), by applying to me, shall be gratified, as far as it is in my power; and if the mineral sent to me is thought to be of any use to society, an accurate analysis of it shall be made free of expense.

"P. S.—Since writing the above, I have examined another specimen of this manganese, weighing one pound.

"Two ounces of it reduced to powder, heated in an iron tube, in one of Lewis's black lead furnaces, yielded eighty cubic inches of oxygenous gas, which tested by phosphorus in the eudiometer of Fantana, left behind about three per cent azotic gas.

"One measure of the oxygen gas, passed

up over lime water, gave a portion of carbonate of lime, barely perceptible.

"One ounce measure of muriatic acid, heated upon one ounce, by weight, of it over water, afforded forty-five cubic inches of oxy-muriatic gas, in which leaf copper, commonly called Dutch metal, immediately inflamed.

"Its specific gravity, at the temperature of 62° of Fahrenheit's thermometer, and before it had absorbed water, was 3.4193. After (and the absorption accelerated by thirty minutes boiling in water), it rose to 3.7667.

"Like all the other ores of manganese, it is combined with iron, siliceous earth, etc. A deep blue precipitate takes place, upon adding the prussiate of pot-ash to a solution of it in the muriatic acid."

In 1807 Woodhouse sent a most interesting account of the zinc mine at Perkiomen to the *Medical Museum.* He gave an exhaustive analysis of the ore which was sphalerite. The mines in that vicinity were subsequently operated but it will be recalled that the large quantity of this mineral proved a serious detriment, because no market could be found for the same in this country. . . . How different the situation within the recollection of the

generation still living! These facts, in mind, the subjoined communication takes on an added interest:

"SIR,

"The zinc mine, an account of which you have requested for the *Medical Museum*, is situated on the side of a high hill, on the bank of Perkiomen creek, about twenty miles from Philadelphia. The miners have made excavation to a considerable distance, on the side of the hill, in which a man can walk in a stooping posture. They have also nearly completed a shaft on the top of the hill. The surface of the earth is covered with large masses of compact and laminated sulphate of barytes, iron pyrites, rock chrystal, quartz, etc., which have been dug up from the bowels of the earth, in sinking the shaft, and making the excavation.

"Three varieties of ore are found in the mine; the lead coloured, the yellow, and the deep black.

"The specific gravity of the lead coloured (which is the most abundant), at 60° Fahrenheit, is 5.3121.

"Two thousand grains of this ore, reduced to an impalpable powder, and exposed two hours to the intense heat of an air-furnace, lost 900 grains in weight, which consisted of water and sulphur.

"One thousand grains of the powdered ore were boiled an hour in an oil flask, with two ounce measures of sulphuric acid. Water was added to this mixture, which being filtered and evaporated, produced a compact mass of sulphate of zinc or white vitriol, weighing 1,730 grains. A residuum was left in the flask, which weighed 508 grains; upon exposing it to heat, 262 grains of sulphur sublimed from it, and the residuum in the subliming vessel weighed 246 grains, which, boiled in an ounce measure of sulphuric acid, yielded 200 grains of white vitriol.

"The residuum from the 246 grains was mixed with potash and exposed to heat, when it formed a brown mass, which being powdered and dissolved in water, formed the liquor of flints from which the silex was precipitated by the muriatic acid.

"One hundred grains of the ore were dissolved in an ounce and a half measure of nitric acid, diluted with an equal quantity of pure water. Ten grains of a residuum remained, which, when viewed through a microscope, appeared to consist of fragments of grey quartz, mixed with globules of sulphur. The zinc was precipitated from this nitric solution by mild potash, and, when dry, it weighed 140 grains.

"It is said by chemists, that the weight of the oxide of zinc, precipitated by mild alkali from its solution, will amount to 193 grains, for every hundred of the metal it represents.

"According to this calculation, one hundred grains of the Perkiomen ore, must contain 72 of the metallic zinc.

"The white vitriol obtained from 1,000 grains of the ore, was dissolved in pure water.

"Plates of metallic zinc were left in this water, for several days, when 26 grains of metallic iron were precipitated.

"Metallic zinc was procured from the ore mixed with charcoal, by exposing the two substances to the heat of an air-furnace, in a coated earthen retort, to the neck of which a tin tube was luted, which communicated with water, in order to keep off the action of the oxygenous portion of the atmosphere.

"Brass was manufactured by mixing the powdered ore with charcoal, and laying pieces of copper on the surface of the coal, and exposing the whole to the heat of an air-furnace, in a covered crucible, for several hours.

"Similar experiments were performed on the black ore, with nearly the same results.

"According to these experiments, 100 grains of the Perkiomen ore consists of about 72 parts zinc, 22 sulphur, 3 iron, and 3 silex.

Some specimens of it contain a portion of lead.

"These proportions are not given as just, for it is almost impossible to analyse a zinc ore with perfect accuracy. We can only approximate to the truth.

"It is not exactly fair to deduce the quantity of metal a zinc ore may contain, from the weight of it precipitated by a mild alkali, as recommended by Nicholson; for this weight will vary with the quantity of water which may adhere to it.

"If we attempt to analyse the ore by manufacturing it into brass, as recommended by Accum, who considers this process as *tolerably* accurate, we lose a large quantity of the metal, which escapes in the form of flowers of zinc."

For curiosity's sake contrast the analysis of Woodhouse just given with that of a sample of the ore from the same locality made by J. Lawrence Smith, ninety years later:

	Woodhouse	Smith
Quartz (silex)	3.00	....
Sulphur	22.00	33.82
Zinc	72.00	64.39
Cadmium	....	0.98
Copper	....	0.32
Lead	(sometimes)	0.78
Iron	3.00	....

And Woodhouse continues: "Can this ore be worked to advantage in the United States?

"No information on this subject can be obtained from any book with which I am acquainted. Dr. Meade, a gentleman possessed of extensive knowledge on mineralogy, informed me that it is never worked in England. Dr. Bruce, professor of this science, in the college of physicians, New York, told me it is reduced in Wales; and Mr. Godon, of Boston, who is extremely well acquainted with subjects relating to this business, has declared that zinc cannot be obtained from this kind of ore in the large way, but with the utmost difficulty."

The analytical portion of this paper is in accord with that of the day. It will cause the young analyst to smile. The method of arriving at the sulphur content of the ore will stagger him. It is quite certain that the introduction of "plates of metallic zinc . . . in this water, for several days . . . precipitated '26 grains of metallic iron' " will develop criticism. Could Woodhouse have examined that deposit? Is it not probable that lead was in the metal thus obtained? It is quite well known that cadmium salt solutions have been deprived of lead in the manner described.

An unhappy conclusion, attending Woodhouse's communication on the zinc ore, was

that it called forth a cruel criticism from Dr. A. Seybert, who must have harbored unkind feeling toward Woodhouse, who years before had been his competitor for the professorship of chemistry (p. 00). Seybert's life conduct was, as a rule, so exalted that this outburst in the *Medical Museum* was most unworthy of him. Hence it will be passed over. Its nature will be sufficiently indicated by reading between the lines of Woodhouse's reply:

"In a work dedicated to the interests of science, it ought certainly to be expected that those whose leisure or opportunities permit them, occasionally, to throw in their contributions to the general stock of knowledge, would discard everything like asperity in their remarks on the opinions advanced by others; and that the little passions of envy and jealousy would never actuate the minds of those, whose real object is the pursuit of truth.

"It was, therefore, with surprise, mingled with regret, that I perused the paper inserted in your last number by Dr. Seybert, on the subject of the Perkiomen mine.

"As it is of little consequence to the public whether or not Dr. S. knew that blende or the sulphuret of zinc was found near Perkiomen in 1806; and it is equally immaterial, whether or not, in 1807, when shown a specimen of this

same ore, he declared it to be lead ore; I shall proceed to show that his essay, improperly entitled "Facts (when it entirely consists of quotations) to prove that this metallic ore can be worked to advantage in the United States," proves nothing, except the doctor's misplaced rancour against myself, and which my former essay has furnished him a pretext for exhibiting.

"Without entering into a comparison of the doctor's patriotism with my own; without pretending that my attachment to my *natale solum* is as strong as his; or that I should be disposed to make as great sacrifices, either personal or pecuniary, for my native country as Dr. Seybert would, I shall show,

"1st. That there is an evident want of candour in the conclusions he has drawn from my publication.

"2nd. That some of his quotations from chemical writers are unfairly given.

"3rd. That what he has advanced bears no direct relation to the subject in question.

"4th. That the observations in his concluding paragraphs are highly personal and improper; and

Lastly, I shall annex correct extracts from the best modern writers to show that the blendes, though they abound, are seldom worked in Europe.

"In the first place there is a want of candour because the doctor asserts that I have maintained that this American ore will yield 72 per cent of metal; whereas I expressly mentioned that this quantity was not given as accurate, from the difficulty of analyzing the ores of zinc, and the reasons are assigned.

"An erroneous conclusion is drawn from what I have published on this subject. In order to place this in a clear point of view, I will insert the two paragraphs which have so much excited the irascibility of the doctor, and let the reader compare them with his remarks.

"Can this ore be worked to advantage in the United States?

"No information on this subject can be obtained from any book with which I am acquainted. Mr. Meade, a gentleman possessed of extensive knowledge on mineralogy, informed me that it is never worked in England. Dr. Bruce, professor of that science in the College of Physicians, New York, told me that it is reduced in Wales; and Mr. Godon, of Boston, who is extremely well acquainted with subjects relating to this business, has declared that zinc cannot be obtained from this kind of ore, but with the utmost difficulty."

"For thus merely stating the information derived from three men of eminence, without

advancing any opinion of my own, Dr. Seybert has taken the liberty of asserting that I assume the principle that blende is not and cannot be worked *anywhere* to advantage.

"Secondly, The quotations from some writers are not fairly stated. This will appear from the following extract from Dr. Seybert's essay, when compared with what has been said by Bishop Watson, and the celebrated Chaptal, on the same subject.

"'At Rammelsberg, near Goslar, there is a considerable manufacture of brass. I visited it in 1794. Here they form this important alloy (cadmia) a sublimed oxide of zinc which is obtained by proper management during the roasting of the lead ores and blendes, in a reverberatory furnace.'

"Here an incorrect idea is held forth, that a mine of *blende* is worked near Goslar in Germany, but the fact is, that the mine at that place is wrought for the *lead* and *silver* it affords; and as no additional expense is incurred from the purchase of fuel, the oxide of zinc is obtained at the same time; and the mine is a *lead*, and not a *zinc* mine.

"Now let us examine what Chaptal and Bishop Watson actually do say on the subject, when divested of the doctor's *alloy*.

"Chaptal, vol. 2, p. 46, 4th Amer. edit.:

'Zinc is sometimes mixed with lead, and in the working of this last metal, the former is *occasionally* obtained. Such is the ore worked at Rammelsberg, near Goslar. Great part of the zinc is dissipated, but a *portion* of this metal is obtained by a very ingenious process.'

"*Watson's Chemical Essays*, vol. 4, p. 40: 'At Goslar, in Germany, they smelt an ore which contains lead, silver, copper, iron, and zinc, in the same mass. The ore is smelted to procure the *silver* and *lead;* but, by a particular contrivance, they obtain a portion of zinc in substance.'

"The slightest observation will show that Dr. S. has taken as much from Bishop Watson's work, as would suit his purpose, without any regard to conveying the true meaning of the author.

"It is true, the Bishop says, vol. 4, p. 20: 'The sulphuret of zinc has for many years been used, as well as calamine, for the making of brass at Bristol;' but, in p. 40 of the same essay, he informs us, that 'as to this ore of zinc, it is not so commonly used as calamine for the making of brass at Bristol. Several ship-loads of it were sent, a few years ago, from Cornwall to this town. Upon the whole, however, experience has not brought it into reputation at this place.'

"But Dr. S. infers, that because a lead mine in Germany, which is worked for the silver and lead it contans, affords a *portion* of zinc, that therefore a zinc mine, containing little lead and no silver, can be worked to advantage in the United States.

"Thirdly, What the doctor has advanced in near eight octavo pages, bears no direct relation to the subject in question. It is not by quotations from foreign writers that we can determine whether metallic zinc, or any substance into which it enters as a component part, can be worked with advantage in the United States; but by taking into consideration the extent of the ore; the quantity of metal it will afford when worked on a large scale (which can only be ascertained by an experiment with several hundred weight of the ore); the price of labour in this country; the cost of fuel to throw off the sulphur, and afterwards to extract the metal; the demand for the zinc, and the price for which it can be manufactured abroad and imported into this country. Not one of these circumstances has been considered by Dr. Seybert; and yet, with a kind of self-complacency, as if the consideration of these points was beneath his dignity, he says, 'I DO MAINTAIN that the Perkiomen blende can be worked in America with advantage.' There is a trifling

difference, however, between *assertion* and *proof*.

"The question is not whether the blendes are, or are not worked in Europe, but, whether we can manufacture metallic zinc, or compounds into which it enters, cheaper than they can be imported from England, France, Germany, and the East Indies.

"Calamine, an ore of zinc, which can be easily and profitably wrought, abounds in Great Britain. 'As we have greater plenty of calamine in England,' says Bishop Watson, 'and that of a better sort, than most other nations have, there is no fear of our losing the advantage in this article of trade, which we are now possessed of.' *Essays*, vol. 4, p. 7.

"The blendes of Perkiomen also differ, *materially*, from those of other countries; and they all differ from each other.

" 'The nature of the sulphurets of zinc', says *Fourcroy*, vol. 5, p. 519, 'is not well known, and Bergmann found such great difference between them, from different countries, that the ores seemed to possess no identical properties or composition.'

"Fourthly, The observations in the concluding paragraphs are highly personal and improper. Although I had advanced no opinion, the doctor has undertaken to *denounce* me as one 'exciting unfounded doubts, propagating erroneous opin-

ions, and *attempting* to *paralize* the wise efforts of a judicious public,' (although no efforts have ever been made by the public, to work the Perkiomen mine), 'and at a time when the political situation of our country is such, that its foreign relations are interrupted, and much is expected from an energetic application of its internal resources.'

"In France, during the gloomy periods of the revolution such a denunciation would have been sufficient to bring the object of it to the *guillotine*, and, *were it true*, it ought, even here justly to excite the hatred of my fellow-citizens against me. But I repel the insinuation with the contempt it deserves. In every analysis I have made, public utility has been my sole object, and to that object my attention has always cheerfully been devoted, without any regard to labour or expense.

"Correct extracts from the most celebrated modern writers are annexed, which prove that the blendes or sulphurets of zinc are *seldom* worked in Europe.

"The abbe Hauy, whom Fourcroy, the great and enlightened historian of chemical science, very justly styles 'the last, most learned and accurate author on mineralogy', after mentioning that the sulphurets of zinc abound in the mines of Saxony, Bohemia, Hungary; that they

are found in Sweden, Norway, England, France, etc., and that, in general, zinc is one of the most common of the metals, informs us, that 'this metallic substance is scarcely an object to seek after, and that it is casually extracted in the melting of minerals with which it is associated, and particularly the sulphurets of lead.'

" 'The sulphurets of zinc are scarcely worked by themselves, or with the sole intention of extracting the metal. It is most frequently by fusion with the ores of lead, mixed with the sulphuret of zinc, that the latter metal is obtained.' *Fourcroy*, vol. 5, p. 522.

" 'Blende is sometimes, although extremely rarely, worked as an ore of zinc.' *Jamieson's Mineralogy*, vol. 2, *article Zinc*.

" 'Zinc is obtained *adventitiously*, in the melting of such copper and lead ores as contain zinc or blende.' Weigleb, p. 419.

" '*I do not know any country where blende is wrought to obtain zinc.*' Chaptal, Amer. edit., vol. 2, p. 46.

" 'As the consumption of zinc is very limited, it has not been worked.' *Chemistry applied to the Arts and Manufactures*, by Chaptal, vol. 2, p. 209.

" 'Calamine is the ore of zinc that is always worked. The extraction of zinc from blende is attempted, but not often.' *Murray*, vol. 3, p. 34.

"'*No mines are worked in order to extract zinc.* In fusing lead ore, mixed with blende, the metal is obtained in the state of an oxide.' *Lagrange*, vol. 2, p. 34.

"I might swell this list of quotations with extracts from other eminent chemical authors; but I shall forebear, as I should, no doubt, meet with this *conclusive* answer from *Dr. Seybert*, that '*those authors do not know all that is done in* this way!'

"The reason that the blendes are not worked, is the great difficulty of throwing off the sulphur they contain. The following experiments have lately been made:

"One pound of the Perkiomen ore, reduced to a fine powder, was exposed eight hours in a blast furnace to the heat of the Lehigh coal, which is much greater than can be excited by any other kind of fuel, and it lost only three ounces in weight. Aqua regia was then added to an ounce of it, and a quantity of sulphur immediately separated and swam on the surface of the fluid. When washed and dried it weighed 150 grains.

"Eight ounces of this roasted ore, mixed with the powder of charcoal, were submitted in a proper manner to the same heat for ten hours, and an inconsiderable quantity of metallic zinc was procured.

"An unsuccessful attempt was also made to manufacture the sulphate of zinc, or white vitriol, in the same manner as they do in some parts of Europe, by submitting a lump of ore, weighing two pounds, to an intense red-heat, repeatedly extinguishing it in water, and evaporating this fluid to dryness.

"As Dr. S. has made no experiments on the Perkiomen ore, it is absurd for him to pretend to give information to others on this subject, when he possesses none himself.

"For my part, I would sincerely rejoice to see this or any other metallic substance wrought *to advantage* in this country; coinciding freely in the opinion of the illustrious Chaptal, 'That although AGRICULTURE is the basis of the public welfare, the ARTS and COMMERCE form the *glory*, the *ornament*, and the *riches* of every polished nation.'

"I shall now conclude my reply to Dr. Seybert by introducing a letter on this subject, which has been addressed to me by a mineralogist, who, in that science, is second to none, either in this or any other country.

" 'SIR,

" 'The question at present between you and Dr. Seybert is, whether it be possible to use, *with advantage*, the blende of Perkiomen in the manufacture of zinc and brass. It appears to

me that the solution of this question is beyond the limits of chemistry, and mineralogy, and become a question merely of speculation. On this point, I think the quotations from European authors perfectly useless, for none of them declare positively that any benefit has resulted to those who have tried this experiment. Besides, their authority must pass for nothing as regards America, where circumstances are so different from those of Europe. I have no hesitation in giving my opinion against a manufacture intended for the transformation of *blende* into *artificial calamine*, in a country where I am as yet unacquainted with any mine of copper being in *actual exploration;* but my idea on this subject may be susceptible of some modification, as I am not sufficiently advanced in a knowledge of the country, to have ascertained the price of various articles necessary to the manufacture, and to render it really serviceable.'

"Dr. S. anticipates the near approach of a time, when we shall see the articles of zinc and copper, as forming interesting items in the list of articles exported from the United States. If this should prove correct as to *brass*, it certainly never can be so as to *zinc*. I have always seen that metal at so low a price, and in so little demand in Europe, that it is very doubtful

whether that part of the world (the only place to export to) will ever present an advantageous market for zinc *manufacturers in America.* But if, in fact, Dr. Seybert has a good opinion of the utility of exploring this mine, a natural *proof* presents itself corroborating his own opinion, and proving that what he advances to the public is the *fruit of reflection.* It is said he is wealthy; let him furnish the funds, and his information towards an object of which he has so high an idea, and which ought now to afford a greater prospect of success, as a mine of copper, of which *he had no knowledge at the time of publishing his essay,* has just been discovered near that containing this blende. For my part, I sincerely hope that this business may succeed; but so far I see no reason to change my opinion."

Would that these scientists could have lived to see the working of zinc ores in Missouri, Pennsylvania, New Jersey, and elsewhere. Changes do come with time and further knowledge!

A striking feature of Woodhouse's character, manifest in all his work, was an overweaning ambition to serve his country.

Curiously, the examination of the literary remains of even the most eminent chemists of the earlier days, reveals that at some time they

suggested the making of inks of various sorts. Woodhouse was no exception. He did not believe that it in any wise compromised his dignity as investigator or professor. Thus it happened that in response to a desire of John Redman Coxe of the *Medical Museum*, who became in time his successor, he wrote, "a receipt for making an indelible ink, superior to that imported from London." Perhaps it may have a present value, for which reason it is here incorporated.

"Dissolve four drachms of the nitrate of silver or lunar caustic of the shops, in four ounce measures of rain or river water, and when the solution is clear, add to it sixty drops of an infusion of galls, made by pouring a gill of boiling water, on two drachms of powdered galls.

"Dissolve one ounce of pearl-ash in four ounce measures of water, and let it stand until the solution becomes clear.

"Dip a flat stick in the solution of pearl-ash, and impregnate the article in the part to be marked with it, and let it be well dried. Then write over it, with a clean pen, having a stiff nib, dipped in the solution of lunar caustic, holding the gallate of silver suspended, and the letters will be formed of a black colour.

"When an infusion of galls is added to a solu-

tion of the nitrate of silver, the gallic acid unites to a portion of the oxide of silver of the nitric solution, and forms gallate of silver, which remains for a short time suspended in the solution, and makes the ink, which consists of gallate and nitrate of silver, flow from the pen in an equable manner.

"When the ink comes in contact with muslin, linen or cotton, impregnated with the solution of pearl-ash, a double elective attraction takes place. The gallic and nitric acids, unite with the pearl-ash and form gallate and nitrate of pearl-ash; the carbonic acid of the pearl-ash joins the oxide of silver, and makes carbonate of silver, which is deposited upon the part written.

"When articles marked with this indelible ink, are washed, the gallate and nitrate of pot-ash, being soluble in water, are carried away, and the carbonate of silver remains behind.

"When the gallate of silver has fallen to the bottom of the nitric-solution, the vessel containing it, must be frequently shaken, to keep it suspended.

"The quantity of ink, mentioned in this receipt, will fill forty bottles, of the size imported into this country.

"The pot-ash contained in the vials brought from London is coloured with cochineal or red saunders."

The various chemical reactions outlined in this receipt could sustain a revision without loss. Present day explanation would differ considerably.

Before the active period of Wöhler and Liebig there were chemists who were unable to resist the fascinating power of the destructive fulminates. The work of Howard and Brugnatelli in this field is so well known that a review of the same in this place would be superfluous, and nothing would be said of them were it not that in a letter to his friend Mitchill, Woodhouse recited his personal experiences in this direction. After alluding to the shortcomings of the existing methods and his failure to realize any success with them, he says:

"My mode is as follows:

"Take two ounce measures of a saturated solution of the nitrate of mecury in water, and pour it into a quart tumbler. Add to it four ounce measures of alkohol, and then two ounce measures of the best and strongest nitric acid.

"Immediately an effervescence will take place, and an immense quantity of nitrous etherized gas, and nitrous air, will be discharged in thick clouds, and in about fifteen minutes the fulminating mercury will be deposited at the

bottom of the vessel, in beautiful slender crystals of a white and brilliant colour. They must be washed by filling the tumbler twice with pure water, and then dried by a gentle heat, or by exposing them two days to the air. The proportion of ingredients here mentioned will yield two hundred and twenty-seven grains of this exploding preparation. The process never fails, is cheaper, more easily and speedily performed, and yields a larger product than any other yet known."

Some years later he was moved to write at some length on this subject, as he believed the salt might be applied to purposes of war, particularly in perforating the timbers of vessels. Among other observations he said:

"A brick-bat, weighing five pounds, was placed upon fifteen grains of this fulminating mercury, lying upon an inch plank. A train of gun-powder was made to communicate with the fulminating compound. Upon firing it, a piece of the plank, several inches in length, was torn off.

"Thirty grains fired in the same manner, split the brick in two, perforated the plank, and tore away a piece of it, five inches in length, and two in breadth.

"Sixty grains, placed on a three inch plank, with two brick-bats over them, broke the bricks into a variety of pieces, scattered them in every

direction, and made an excavation in the plank, half an inch deep, and five in circumference.

"Ninety grains, under five bricks, broke the whole into an immense number of pieces, perforated the three inch plank one inch deep, and nine in circumference.

"Two hundred grains were laid upon an oak plank five feet in length, and one foot in breadth. Another plank of the same size was laid over the fulminating mercury, and confined by thirty pounds weight of bricks. Upon firing the compound, all the bricks were broken into pieces; a foot in length and breadth of the table on which the planks rested was carried away; the upper plank was thrown into the air; both were split and small excavations made in them.

"An idea of the immense force of this substance may be conceived, when it is related, that ten grains of it will burst the strongest pistol-barrel that can be made.

"As it possesses a thousand times the power of gun-powder, is no ways dangerous, and can be fired by the flint and steel, it would appear to be preferable to this article to charge the torpedoes of Mr. Fulton."

Carbon monoxide, carbonic oxide gas in the

oldest literature, was in Woodhouse's day confounded with carburetted hydrogen. Priestley had called attention of chemists to it when writing on phlogiston. He comprehended its constitution quite correctly, as did also Woodhouse. Berthollet was of those who entertained an opinion different from that held by Priestley. Woodhouse's experiment on the oxide had been transmitted to France, and had engaged the attention of the National Institute. Cruickshanks of Woolwich in the meantime redetermined its composition, and thus confirmed the views of Woodhouse and Priestley. It is interesting in this connection to hear T. E. Thorpe:

"If, too, as you draw up to the fire 'betwixt the gloaming and the mirk' of these dull, cold, November days, and note the little blue flame playing around the red hot coals, think kindly of Priestley, for he first told us of the nature of that flame when in the exile to which our forefathers drove him."

Devoted to botanical studies, plant chemistry was a delight to Woodhouse. Witness his thesis (p. 18) and the rôle played by plants in atmospheric purification (p. 185). Consequently the subjoined observations were in the line of

his activities. His friend Mitchill designated them "an important article of intelligence." They had reference to the caoutchouc found in certain milky plants, near Philadelphia. Woodhouse observed:

"During the summer season I made a variety of experiments upon the milky plants of this country, and find that many of them, as Apocynum Cannabinum or Indian Hemp, Sonchus Floridanus or Sowthistle, Asclepias Suriaca or Syrian Swallow-wort, Euphorbia Picta or Painted Spurge, and a few others yield a product which possesses nearly the same properties as the Caoutchouc of South America.

"The milk in these vegetables answers the same purpose as the blood in animals, and may very properly be called the white blood of plants. When this kind of milk is received in a vessel exposed to the air, it separates, like the blood of animals, into two parts, serum and crassamentum. If it is exposed in contact with the air of the atmosphere, confined by water, the oxygenous portion of this air unites with the coal of the crassamentum and forms carbonic acid gas, by which means the purity of this air is greatly diminished.

"When a wound, ever so minute, is made in one of these milky vegetables, it immediately begins to bleed, and death would ensue, did not

a coagulum quickly form round the abraded part. We find the same circumstances take place in animals which have been wounded.

"The natives of South America make torches of the Caoutchouc; and the coagulum of our native milky plants is equally as inflammable as the gum-elastic, and burns exactly in the same manner, giving a vivid light, and throwing off a considerable quantity of lamp-black, or the charcoal of oils.

"When the white juice of the Apocynum Cannabinum is received in a cup, it immediately coagulates; the coagulum may be drawn thirty times its length, and it will instantly contract again to its original size.

"The caoutchouc, and the coagulum of our lactiferous vegetables, exposed in a glass tube to a red heat, yield a portion of the oil of turpentine, and large quantities of carbonated hydrogenous gas, which has a very disagreeable smell."

There is apparent also in this communication, reference to public welfare and service. It is seen constantly in his writings. It comes strongly to the front in his observations on the stem and root of the Xanthorhiza tinctoria, or shrub yellow root, in which he seeks to apply its tinctorial power as well as its medicinal properties. His description of the plant is so de-

lightful that every one will enjoy reading that:

"The Xanthorhiza tinctoria is a native of North Carolina, and was first brought from that State into Pennsylvania, about forty years since, by Mr. John Bartram, then Botanist to the King of Great Britain, and planted in his garden at Kingsess, in the county of Philadelphia, where it has continued to flourish in a most luxuriant manner. The stems reach the height of three feet, and are generally somewhat thicker than the barrel of a goose-quill. The root is from three to twelve inches long, about the diameter of a man's little finger, sending off numerous scions, sometimes two feet in length, by which means it spreads considerably."

He next refers to its *CHARACTERS OF FRUCTIFICATION*, and after emphasizing that the stem and root of the xanthorhiza are of a bright yellow colour, and possess a strong bitter taste, he outlines experiments made with different parts of the plant, "to ascertain its virtues."

"1. Pump-water, digested on the stems and roots in coarse powder, received a yellow colour and tasted bitter.

"2. Water, repeatedly boiled on the stems and roots, extracted the greatest part of the colouring matter.

"3. The stems and roots, distilled with a gentle heat, produced some water, which contained none of the qualities of the plant.

"4. One pint of alkohol, digested in half an ounce of the bruised roots, contracted a deep yellow colour, and possessed an intensely bitter taste.

"5. This alkohol, being filtered, gave, by spontaneous evaporation in the open air, two scruples of a yellow resinous extract.

"6. One pint of alkohol and water, digested on half an ounce of the bruised roots receives a pale yellow colour.

"7. This diluted alkohol, evaporated to dryness, left thirty grains of extracted matter.

"8. Water, added to the tincture of the stems and roots in alkohol, rendered it muddy.

"9. Pieces of silk, cloth, flannel, cotton and linen, were boiled in a decoction of the powdered stems and roots. The silk received a bright yellow colour, the cloth a drab, the flannel a pale yellow, and the cotton and linen would not take the colouring particles.

"10. This silk, cloth and flannel, were exposed, twenty days, to the action of the solar light, in a temperature varying from 105 to 115 deg. of Fahrenheit's thermometer, along side of other pieces of the same kind of stuffs, dyed with fustic, saffron, and turmeric.

"In a few hours the light and oxygen of the atmospheric air altered all these colours a little, except that of the cloth. The colouring matter of the tumeric first disappeared, then of the saffron—that of the Xanthorhiza stood nearly as well as the fustic.

"11. Pieces of silk were boiled in the following mordants: Solution of alum, alum and pot-ash, or sulphate of pot-ash and alumine; cream of tartar and alum, or tartrite of alumine and sulphate of pot-ash; saccharum and alum, or sulphate of lead and acetate of alumine; and the murio-sulphate of tin. They were then dyed with the Xanthorhiza, and received different shades of yellow. Other pieces of silk were also boiled in the same kind of mordants, and dyed with quer-citron bark, weld, fustic, turmeric, saffron, and the roots of hydrastis canadensis, the simple tincture of which imparts to silk a rich and superb yellow colour. The whole were exposed to the light of the sun, in atmospheric air, twenty-seven days, in a temperature varying from 110 to 115 deg. of Fahrenheit. The colouring matter of the tumeric and saffron was the most fugitive. The silk dyed with the quer-citron bark, with saccharum saturni and alum, for a mordant, stood best. The others contracted a brown cast, except the weld, which had faded.

"12. A portion of the roots grated, mixed with a small quantity of water, strained through a rag, and evaporated to dryness in the shade, produced a yellow extract, which was mixed with a portion of alum.

"13. Paper was coloured yellow with this preparation, and green by mixing it with Prussian blue. This paper was exposed to the light of the sun in a temperature of 105 deg. of Fahrenheit along side of other paper, stained in a similar manner with gamboge. In a few hours the yellow and green of the Xanthorhiza were considerably altered for the worse, while those of the gamboge were not affected.

"14. The leaves, stems and roots separately burnt in the open air, yielded ashes, to which warm water was added. The water being filtered and evaporated to dryness, produced a small quantity of pot-ash. Some siliceous and aluminous earth remained on the filter.

"15. A handful of the leaves, exposed three hours to the influence of the solar light, in forty ounce measures of pumpwater, gave twelve drachm measures of oxygen gas, which devoured nearly three equal measures of nitrous air.

"16. A green tincture of the leaves in alkohol was exposed in a dark place to the light of the sun, in atmosphere of oxygenous, azotic, and

hydrogen gases. That which was placed in the oxygen gas, in the light, in a few days contracted a yellow and afterwards a red colour. No alteration was produced in the rest.

"17. A stem, two feet long, was placed in a solution of nitre, and of the sulphates of iron and copper. All these agents were taken up by the absorbents of the plant, and deposited in the leaves. The iron was detected by placing the stem in the distilled acid of the unripe fruit of the Diospyros Virginiana, or persimmon tree; the copper, by putting it in ammoniac, when the leaves were turned of various shades of brown. The presence of the nitre was shown by setting fire to the leaves, when they burnt like paper soaked in a solution of this salt.

"It appears, from these experiments, that the Xanthorhiza tinctoria contains a gum and resin, both of which are intensely bitter; the resin being more abundant than the gum. From the small quantity which is obtained from half an ounce of the stem and root, by one pint of alkohol, it is probable that part of it is carried off in the vapour of this volatile fluid.

"It imparts a drab colour to cloth, and a handsome yellow to silk, but the dye will not take on cotton or linen, as the colouring particles have no elective attraction for these stuffs. The different mordants which were

used altered the shade of the yellow colour considerably, but did not appear to render it more permanent. While every shade of this elegant colour can be obtained from that truly valuable drug, the quer-citron bark, I think it will always supercede the Xanthorhiza, and every other native yellow dye, among which that of the hydrastis canadensis may justly be reckoned the most superb.

"The watery extract of the grated roots, mixed with alum, and added to Prussian blue, was first used by Mr. James Bartram, for colouring plants, and the plumage of birds, of a green colour. The green is far more lively and elegant than that made with gamboge and Prussian blue, which is generally used for painting in water colours, and stands well in the shade, but soon contracts a dull colour when exposed to a bright light, and to a high temperature. Various subjects, coloured by this green, one year since, and inclosed in a book, are as lively at this time as when first painted.

"The leaves, exposed in pump-water to the light of the sun, afforded air of a high degree of purity. This air arises from the decomposition of the carbonic acid which is contained in most water. The carbon of this acid unites to the leaves, while its oxygen is set at liberty. As no pure air can be obtained from these, or any

other leaves, in distilled river, rain or lime water, and as, from numerous experiments, I never could find that they purified common atmospheric air, when inclosed in it, and exposed to the light of the sun, unless it contained fixed air, I believe the opinion which is almost universally adopted, that they give to man oxygen gas in any considerable quantity, and that he yields them azotic air in return, to be totally false.

"The colour of the leaves appears to reside in a resin, which is altered by the combined action of light and oxygen, by either of which, separately, it cannot be affected. Vide experiment 16.

"Nitre, the sulphates of iron and copper, ammoniac, and the gallic acid, were taken up by the absorbents of the stem, and carried to the leaves. The hyperoxygenated muriate of potash is an excellent agent to demonstrate these vessels in the leaves of some trees, as those of the Franklinia alatemaha, Corylus avellana, etc., when they become of a deep brown colour. When a leaf of Liriodendron tulipifera was impregnated with nitre, and set on fire, it burned principally along what have improperly been called the nerves of the leaf, but which are now known to contain absorbent vessels.

"As the Xanthorhiza tinctoria is a strong and

pleasant bitter, and very nearly allied to the celebrated columbo root, it promises to become a valuable addition to the American Medica. It is preferable to all out native bitters. The bark of the root of the Aristolochia sipho, or Dutchman's pipe, which is often made use of by the inhabitants near Pittsburgh is a weak aromatic bitter. The root of the Actea racemosa, black snake-root or rich weed, is a nauseous bitter. The bark of the root of the Liriodendron tulipifera, tulip or poplar tree, is more pungent and aromatic than bitter. Chironia angularis, or centaury, Gentiana saponaris, or blue gentian, Veratrum luteum, or devil's bit; the red berries of cornus florida, or dog wood; and the bark of several species of Salix, or willow, are weaker bitters than the yellow root.

"I have often used the powdered stem and root of the Xanthorhiza with success, in the dose of two scruples to an adult, in many of those diseases in which bitters are recommended, but generally combined with other remedies. It is a medicine which sits easy upon the stomach, and produces no disagreeable effects."

Reading a communication showing such excellent results, one cannot help but admire the breadth of Woodhouse's scientific purposes.

The people of this new country were to profit as far as possible from their natural resources, aided by chemistry.

In 1807, on Monday, the 14th of December, a meteor fell at Weston, Connecticut. Portions of this meteor were also found six and ten miles distant from each other. The fall attracted a large group of interested scientists, among whom was Woodhouse. What he had to say and the analysis he made have been preserved. They are reproduced because of the value they possess, even at this distant date.

"The specific gravity of a specimen of one of these stones was 3.696, at the temperature of 62° of Fahrenheit's thermometer.

"Like the meteoric stones of other countries, when viewed through a microscope, they are found to consist,

"1st. Of pyrites of a silvery colour,

"2dly. Of a substance of an orange or yellow colour, which is owing to the oxidation of the iron they contain, by means of water; for these colours did not appear previous to putting the stone in water, in order to ascertain its specific gravity.

"3dly. Of an ash coloured substance, and,

"4thly. Of small bodies of a round, irregular, elongated or elliptical figure, and black colour, containing metallic iron.

"One of these stones, weighing a hundred grains, moved the south pole of a magnet seventeen degrees, and kept it stationary.

"One hundred grains of the stone were reduced to a fine powder. Upon passing a magnet through this powder, twenty-two grains of it were separated.

"According to an analysis of one hundred grains of one of these stones, they were found to consist of

Silex	50
Iron	27
Sulphur	7
Magnesia	10
Nickel	1
	95
Loss	5
	100

"The sulphur was seen distributed through the silex, by the naked eye, in round globules, the size of a pin's head, after dissolving the powdered stone in diluted nitric acid.

"The quantity of nickel is guessed at; but the presence of this metal is evident, from the

green colour of the muriatic solution of the stone, and from the purple precipitate which takes place, upon adding the prussiate of ammoniac to a filtered solution of the stone in marine acid, after it is saturated with alkaline gas, and the iron separated.

"An elaborate account of this meteor has been published by Messrs. Silliman and Kingsley, of Yale College, Connecticut."

Silliman, writing his friend, Kingsley, on January 23d, 1808, evidently had the preceding report in mind.

"DEAR KINGSLEY,

"I am by no means ripe for an ultimate account of everything, yet, knowing your keenness for letters, I now begin a few memoranda. We arrived on Wednesday morning, after riding all night through New Jersey. The night was very cold, and we suffered much, but as Miss W—— was very solicitous to get forward, I would not hang back. Anecdotes of the journey will come better orally,—there were, however, none of any moment,—but I hasten to Philadelphia. I attended Woodhouse's lecture the day after I arrived. He received me politely, but made no allusion to the offensive part of his letter. He showed me his laboratory, which is a very fine one indeed. I dined with him yesterday and met a large party of savans. I cannot

stay to relate many particulars. (Monday 25.) The meteor is immediately brought forward in every circle where I go. It was so at Woodhouse's. He was very modest and even ridiculed the lunar theory which he advocated in his letter."

There has not been discovered a letter from Woodhouse containing "the offensive part." Perhaps he had anticipated Silliman and Kingsley in the announcement of his results. He was ostensibly glad to renew acquaintance with his old pupil. It is worth noting that he brought him in contact "with a large party of savans."

Early in 1808 Woodhouse was engaged on the question of the cooling of water by evaporation, when he wrote:

"It is a fact well known to philosophers, that evaporation always generates cold, and that the temperature of bodies is reduced according to the volatility of the fluids applied to them, and to the warmth and dryness of the atmosphere. . . .

"In India, Persia, and Egypt, they make their drinking cups of a soft porous clay, which, by

suffering some of the water to transude and evaporate, cools the rest.

"Russel, in his History of Aleppo, informs us, that the Turks cool their wine, in the summer season, by wrapping a wet cloth round the bottle which contains it, and exposing it to the rays of the sun.

"Dr. Pinkard tells us, that at Barbadoes they make the wine and porter very pleasantly cool, by putting the bottles in wet cloth bags, and placing them in the open windows for some time before dinner, taking care to sprinkle them occasionally with water as they stand exposed to the breeze.

"Although the thermometer never descends to the freezing point, and ice is never discovered, at Calcutta, in the East Indies, in the pools or cisterns, or in any of the waters collected in the roads, yet, by evaporation, the inhabitants make a sufficient quantity of it in the winter for the supply of the table during the summer season.

"Travellers all agree, that water may be rendered cool by evaporation; but none of them have informed us of the exact degree of temperature to which it may be reduced, by means of a thermometer, the only accurate mode of ascertaining the fact.

"Witman, in his Travels in Turkey, Asia

Minor, and Syria, speaks of its being rendered extremely cool.

"In order to find how low water could be cooled in Philadelphia, one of the vessels which the natives of India use, was procured, and two others were made exactly like it, one of our common clay, and the other of clay and charcoal, both burnt and unglazed. These vessels were filled with water of the temperature of 52°, and were kept swinging in the sun and shade, for several hours at a time, when the temperature of the atmosphere varied from 86° to 110°. The temperature of the water in all the vessels was raised from 52° to 80° and 100°, and they appeared to have no other effect than in preventing it from becoming disagreeably warm.

"As evaporation is always in proportion to the warmth and dryness of the air, it can easily be conceived, that water may be cooled in Egypt by these vessels, and particularly when the kampsin or sirocco wind blows; for this air is so very warm, that it appears as if issuing from the mouth of an oven."

Seriously and sympathetically concerned in the development of chemical industries in his native land, Woodhouse, as early as 1804, wrote John Redman Coxe:

"Too long have our citizens been dependent upon other nations, for many articles, to purify or fabricate which, requires but a small capital, and a very slight degree of chemical knowledge.

"Among the subjects which we may consider as coming under this head, is the obtaining of refined camphor, from the raw material.

"Crude camphor is imported by our merchants from Canton and Batavia, where it is bought for fifty and seventy-five cents, and sells in this country, from a dollar, to a dollar and eleven cents a pound.

"Eight years since, the refining of this article, was confined to two druggists in the United States, and at this time there are not more than eight persons, who accurately understand the process, all of whom keep it a profound secret."

And then he proceeded to describe the apparatus necessary for a refinery. He claimed it was simple, inexpensive and occupied little room. His description reads:

"It consists of a furnace, supporting a sand-bath, glass vessels, and iron, copper or earthen pans.

"A furnace sufficiently large for one active and industrious man to attend, will occupy the space of eight feet nine inches in length and two feet six inches in breadth. It must be made of seven cast-iron plates, half an inch thick, thirty

inches long and fifteen broad. These plates are to be placed upon eight piles of bricks, parallel to each other, and nine inches apart. The bricks are to be ten inches high, thirty long, and six broad.

"Great care must be taken, that the lower sides of the plates meet each other exactly midway on the upper side of the bricks, which should be well covered, with a thick bed of mortar. Bricks serve to confine the sand. When the furnace is connected with a wall, there is no occasion for more than a single row of them: and to obtain a considerable draught of air a chimney should be carried from the fourth plate, with an aperture four inches in diameter, and the flues of the third and fifth plate, may be carried from the second and sixth plates, and the first and seventh should enter the second and sixth.

"The chimney, if convenient, may be made to enter into that of the house, but if not, it should be about fifteen feet high.

"The glass vessels may be procured at a glass-house and are made of green glass. They should be blown as thin as an oil flask. They should be circular in form, shaped flat like a turnip, and have a neck from one to three inches high, with an aperture, from half an inch to one inch in diameter. Their bottoms should

be eleven inches broad, and the top ought to be four inches from the bottom.

"They would cost twenty-five dollars a hundred in Philadelphia.

"Fourteen pans may be made of iron, copper or earth. Sheet iron is the best material. They should be round, one foot in diameter, with a rim pecked on four inches and a half high, and ought to have two small handles. They would cost one dollar a piece in this city.

"Having prepared for this necessary apparatus, the next thing is to make use of it, in such a manner, as to refine the camphor.

"Having taken the article out of the tubs, the glass vessels should be filled two-thirds full of it, and the apertures in the necks, slightly stopped, with paper or cotton plugs. They should then be placed on the bottom of the pans, and covered near to the base of their necks with sand.

"The pans, holding the vessels containing the camphor, should be carried to the sand-bath, and surrounded near to the top of the rim with sand.

"Kindle a gentle fire in the furnace, at four o'clock in the morning, and gradually increase it until the camphor melts, which it does when it arrives at 304° of Fahrenheit's thermometer. It will first rise in flowers, which will dissolve,

and run down the sides of the vessel. When it has melted, or is boiling, the glass should be elevated in such a manner that the hot sand, may reach only to the middle of its belly, in order that the cool air may be admitted to the upper surface of the glass, to congeal the camphor as it sublimes.

"Having kept it in a liquid or boiling state, from eight to ten hours, the refined camphor will be found, adhering to the upper side of the vessel, and should be taken from it by breaking the glass while hot, or it may be easily separated from it, by means of a knife.

"Break into pieces the foul parts which adhere to the bottom of the glass, and which cannot be easily parted from it, and sublime a second time, with an additional supply of camphor.

"When the crude camphor is of a white colour, or contains little foreign matter, no addition is to be made to it; but when it is brown or black, one ounce of slacked or quick lime, should be mixed with every three or four pounds of it. The utility of lime in this operation, was noticed by Margraff.

"One man can refine and pack up, from eighteen to twenty-five pounds every day.

"If any of the glass vessels holding the melted copper should crack, which sometimes happens, and which is discovered, by the flowers rising

into the air from their sides and tops, the pans containing it are to be immediately removed to a cool place; and if the camphor is found mixed with the sand, the whole should be put into other vessels, and the operation conducted as before.

"The loss in refining one hundred weight of this article cannot be accurately ascertained, as it depends upon the purity of the crude material, and the care in conducting the process. It cannot be very great.

"Professor Robertson, in a note to Dr. Black's Chemistry, informs us, that in a manufactory in Holland, he saw more than one hundred vessels in a furnace at one time, and that there was but a moderate smell of camphor in the room.

"I hope that this very useful process may become generally known in the United States."

To his friend Coxe he also submitted, in 1805, some experiments made with the Lehigh coal, saying:

"Other inflammable substances, will, no doubt, be discovered in the United States, and should they be submitted to a proper course of experiments, bodies, apparently of the same nature, may be distinguished from one another, important services may be rendered to our citizens, the arts benefited, and a foundation laid for a system of American mineralogy."

Turning to the main purpose of his communication, he added:

"This coal is found in immense quantities, in Pennsylvania, in the county of Northampton, near the river Lehigh. It is of a shining black colour, and stains the hands very little. Its fragments are tabular, as may be seen, particularly after it has been submitted to heat. Its specific gravity is 1.6181. It burns with very little flame, and no smoke; is with some difficulty kindled, and requires a considerable draught of air, to keep up its combustion.

"When perfectly consumed, it leaves behind, a small portion of white siliceous earth, containing no pot-ash, and sometimes coloured brown by means of iron. It does not contain any sulphur.

"Neither the sulphuric, nitric, nor muriatic acids act upon it.

"It does not take fire, when reduced to an impalpable powder, and passed through the flame of a candle.

"A piece of it, red hot, containing about eight cubic inches, was placed in forty-eight ounce measures of atmospheric air over water, and suffered to cool. Upon passing one measure of this air over lime water, in the Eudiometer of Fontana, it gave one per cent of carbonic acid gas. The remainder of the air, after

being freed from the fixed air, was reduced in purity from 100 to 85.

"One cubic inch of it, red hot, suspended in ten ounce measures of oxygen gas, brightened very little.

"The focus of an eleven-and-a-half inch lens, was directed upon a lump of it, confined in a bell-glass, in twelve ounce measures of oxygen gas, over water, when it burnt with a considerable flame, and nearly in the same manner as the James river coal, when a blast of atmospheric air is thrown upon it. The gas was afterwards reduced in purity, and contained fifty per cent of carbonic acid gas.

"A quantity of the coal red hot, being extinguished under water, produced an inflammable air, without any mixture of fixed air.

"Two measures of this gas, and one of oxygen air, exploded by the electric spark, in the Eudiometer of Volta, left behind one measure of hydrogen gas, containing ten per cent of carbonic acid gas. Two measures of each of the gases, by the same means, were reduced to something more than a measure of oxygen air, which was mixed with fifteen per cent of fixed air.

"Four ounces of it, reduced to a coarse powder, were exposed in an earthen retort, to a red heat in one of Lewis's black lead furnaces,

when it yielded three hundred and sixty ounce measures of hydrogen gas, of the same kind as that produced by extinguishing it, when red hot, under water.

"The same coal taken from the retort, and sprinkled with water, and exposed a second time to heat, afforded thirty ounce measures of inflammable air, in the first portions of which, the carbonic acid was barely perceptible.

"The steam of water was transmitted over the coal red hot, confined in a porcelain tube, and it gave hydrogen gas in torrents, mixed with ten per cent of fixed air. Two measures of this hydrogen gas, after the carbonic acid had been separated from it, and one of oxygen gas, left near a measure of inflammable air, mixed with fifty per cent of fixed air.

"A fire was kindled at half past eleven o'clock, by placing a quantity of the Lehigh coal, upon a stratum of common charcoal in a powerful air furnace, which was then filled with equal portions of the two substances.

"As fast as the charcoal consumed, the Northampton coal was added, and at half past one, the furnace was completely filled with it, and two-thirds of it red hot. At four the coal was half consumed, and it continued burning until eleven o'clock at night.

"Five of Wedgwood's thermometer pieces,

put in crucibles made of porcelain, were deposited in different places among the coal, that they might descend in different directions, and some of them be exposed to the greatest degree of heat.

"When they were cool, being measured by the guage, they gave 70, 77, 150, 156, and 159 degrees.

"125 is the highest heat Mr. Wedgwood could ever produce, in a common smith's forge, and 160 in an air furnace, eight inches square. Brass melts at twenty-one, copper at twenty-seven, silver at twenty-eight, gold at thirty-two, and cast-iron at one hundred and thirty of this thermometer. The welding heat of iron is one hundred and twenty-five.

"James river coal, submitted to an experiment of the same kind, burned out in four hours.

"A fire was made with the Lehigh coal in a smith's forge, and two thick bars of iron were placed in it, and welded with great ease, by the proprietor of the furnace.

"The smith, his journeymen, and bystanders were convinced, that the heat was much cleaner and greater, than that of the James river coal.

"As the Virginia coal burns with flame and much smoke, a vast portion of this combustible substance, and the heat generated by it, are lost by passing up the chimney.

"It appears from some of these experiments, that this coal does not unite to the base of oxygen gas, with as much rapidity as common charcoal, and that it decomposes water. Its flame consisting of oxyde of carbon, or carbonated hydrogen gas, arises from this decomposition.

"When it is exposed to a red heat, and contains little water, it gives rise to a peculiar species of inflammable air without any fixed air; but when the steam of water is transmitted over it, in a red heat, the production of carbonic acid gas is very considerable, and when the hydrogen gas, thus obtained, is fired with oxygen gas, the fixed air generated amounts to thirty-five per cent more than when it is procured from coal united to a small quantity of water.

"According to the opinions, now generally adopted by the Philosophers of Europe, the gases, when little water is mixed with the coal, must consist of oxyde of carbon and carbonated hydrogen gas. It will be said, the oxygen of the water, unites to part of the coal, and forms oxyde of carbon, while its hydrogen escapes, dissolves a portion of the coal, and makes carbonated hydrogen gas.

"This explanation is far from being satisfactory, for no oxyde of carbon can be detected in the gases, produced by extinguishing this coal

when red hot under water, or by submitting it to heat in an earthen retort.

"The Lehigh coal promises to be particularly useful, where a long continued heat is necessary, as in distilling, or in evaporating large quantities of water from various substances; in the melting of metals, or in subliming of salts: in generating steam to work steam engines, and in common life, for washing, cooking, &c., provided the fireplaces are constructed in such a manner as to keep up a strong draught of air."

This superiority of the anthracite coal from the Lehigh district over the bituminous coal of the Southern regions was met with generous acclaim. Journals, periodicals, and scientific publications commented most favorably upon the experiments.

One of the very last series of experiments instituted by Woodhouse related to the "raising of wheat flour and buck-wheat meal." One cannot but admire his zeal for the applied phases of chemistry. To him they represented comfort, welfare, progress and wealth, not for himself, but for the country at large. On this new subject he declared it is believed and taught "that the raising of bread is merely owing to a discharge of carbonic acid gas or fixed air; and it has been asserted, that there is no dif-

ference between the properties of flour, and bread when it has been baked."

"The principal argument in support of this opinion is, that all waters which contain carbonic acid, such as those of the Saratoga and Ballstown springs, in the state of New York, easily raise bread.

"It is not my intention to prove that the raising of dough is not owing to an escape of fixed air, but to show,

"First, that flour mixed with water, however strongly impregnated with carbonic acid, will not make light bread.

"Secondly, that the best bread can be made without any fixed air; and

"Thirdly, that a chemical change takes place in the component parts of flour when it is made into bread, and which arises from the decomposition of water.

"A quantity of water, impregnated with carbonic acid, by strong compression, was accurately mixed with buckwheat meal, and exposed to a proper temperature. It exhibited no signs of rising; the meal subsided into a heavy mass, and the water floated over its surface.

"A quantity of yeast was filtered. A viscid residuum remained on the filter, which contained no carbonic acid. Half a teaspoonful of this substance, triturated with warm water, and

well mixed with buckwheat meal, raised it completely in four hours.

"Dough was made from wheat flour, by well mixing it with water containing carbonic acid.

"It was also made with the viscid residuum and water.

"The masses were placed alongside of each other by the fire, and, in the space of a few hours, that made with the residuum was well raised, but the mass from the carbonic acid exhibited no change; and when the two were baked, the loaf made without the fixed air was extremely light and spongy, whereas the other was tough and heavy.

"These experiments clearly prove, that buckwheat meal may be raised, and excellent wheat bread made, without any fixed air; and that water, however strongly impregnated with carbonic acid, and mixed with flour, will not afford good bread.

"The bakers of Paris make this article of an excellent quality, yet all their yeast is brought in bags, in a dry state, from Flanders and Picardy.

"Good yeast contains a large quantity of fixed air; but so little of it is used in raising buckwheat meal and wheat dough, that it cannot have much effect in raising these substances.

"By boiling forty cubic inches of yeast in a glass retort, the mouth of which communicated

with a receiver filled with mercury, fifty-two cubic inches of fixed air were obtained.

"A small loaf of bread was raised with the viscid residuum in one hundred and four cubic inches of atmospheric air, confined by water. In the space of sixteen hours, the air was found to contain forty cubic inches of carbonic acid gas. Upon washing away the fixed air, and testing the atmospheric air by phosphorus, it was found to have undergone no alteration.

"Buckwheat meal was raised in the same manner, and with the like effect.

"These experiments prove, that a chemical change takes place in the component parts of flour, when it is made into bread. No carbonic acid was contained in the dough when it was first made, and yet, in a short time, forty cubic inches of this gas were formed.

"Fixed air is composed of carbon and oxygen.

"As no oxygen is contained in the flour, and no carbon in the water, the oxygen of the water must combine with the carbon of the flour, and generate the air which raises the bread.

"It is difficult to say what becomes of the hydrogen of the decomposed water. It does not unite with another portion of oxygen and carbon to form alkohol for none of this fluid can be procured by distilling dough or buckwheat meal, after they have been raised."

This brief paper is a forerunner of the wonderfully fruitful studies which have since been made on the same subject, and which at present are being augmented and improved so abundantly at many centers of research. It is a fascinating problem—the chemistry of the bakery!

Could Woodhouse have lived to witness the advances in this particular field, he would doubtless have rejoiced that his simple, early efforts had borne such fruit. Indeed, there is not a single subject to which he gave attention, that did not later become an object of intense investigation. He blazed the way in so many fields that it is a pity he could not have lived to behold and comprehend the splendid results which flowed from them. This, however, was denied him. In the prime of life—not yet thirty-nine years old—and after a too brief career, which extended from 1795 to 1809—just fourteen years—death came most unexpectedly, on Sunday afternoon, June 4, 1809. This was the brief announcement in the daily papers. Apoplexy was the cause. He was found dead in his bed. He was unmarried. His collection of medical books went to the Pennsylvania Hospital; his minerals to the American Philosophical Society. Search among his books disclosed nothing that would have aided in the recital of his life story. This is to be regretted.

His untimely death brought sorrow to his friends and colleagues. The students in medicine adopted unanimously this minute:

"*Resolved*, That in testimony of the high respect and affectionate attachment which we entertain for the late Professor Woodhouse, that each of us will wear crape on the arm for the space of one month."

The interment took place on June 7th from his dwelling in Sansom Street, and was attended by Trustees, Provost, and professors of the University, physicians of the city and members of the American Philosophical Society.

The preceding pages give a very true picture of chemical science in America during the years of Woodhouse's activity. From the moment he assumed his professorship (1795) until death laid him low (1809) he was unceasing in his endeavors. He entered upon this career with meagre preparation and equipment, judged by present-day standards, but by steadfast application he gradually grew in power, until his keenest critics were quite ready to acknowledge him as leader and defer to him all questions pertaining to chemistry. Let the American field be viewed from any standpoint, and there appears as the outstanding chemical figure for a decade more or less in that now

far-away period, but one person—*James Woodhouse*, a genuine pioneer in establishing correct ideas on combustion, respiration, and also the composition and decomposition of water. In short, Woodhouse placed this country in sympathy with those European lands which, but a little earlier, had attached themselves to the French standard, and should he not, therefore, be remembered and adequately honored for his achievements? There were others just as deeply interested in these problems but they have left no mark of their presence; they did not participate by actual personal labours in their laboratories in the final overthrow of the old doctrine and the firm introduction of the newer, better views.

Woodhouse was further, a pioneer—

In *plant chemistry*.

In *the isolation of at least one metal* from its hydroxide by an ingenious, original method (p. 189).

In *laboratory experimentation*, convinced that the student could only understand the chemical changes about him if he himself performed experiments, hence his laboratory guide (p. 77) prepared for this purpose.

In *chemical analysis*, no matter how crude and imperfect his methods look in these

days. A just idea of their worth may be best procured by comparing them with the methods in vogue among other chemists of that time, at home and abroad.

In the *elaboration of industrial chemical processes*, for he was a thorough convert to the thought that his science should contribute to the upbuilding of his country among the nations of the world, render itself of use in making happy and comfortable and prosperous the inhabitants of our newly born Republic.

In *chemical research* which became with him an all-absorbing idea, transmitted to everybody about him. Recall its effect upon Robert Hare, who actually surpassed and towered above his master, in his very first independent research.

Woodhouse's example won for him the esteem, not only of his immediate colleagues in the University, but also drew to him such important individuals in the scientific world as Samuel L. Mitchill, John Redman Coxe and many others from various sections of the Union. His pupils loved and honored him. He lived and wrought for them. His was not a selfish life; on the contrary, it abounded in deeds for others, silently, unostentatiously, performed. He went about doing good.

His administrative ability was attested by service as dean of the Medical School. This demanded patience, energy and diplomacy. Woodhouse succeeded to the satisfaction of everybody concerned.

For these numerous reasons and others which will occur to the reader of the preceding pages, there is every reason to be glad and rejoice that the good man, who wrought so well in laying the foundations of chemistry in this broad land, was, beyond dispute, a worthy member of the noble guild of American chemists.

> "Who kindly shows a wanderer his way,
> Lights, as it were, his torch from his own torch—
> In kindling other's light, no less he shines."

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